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Study of Submarine Casualty Control Training

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STUDY OF SUBMARINE CASUALTY CONTROL TRAINING

ABSTRACT

The increasing complexity of the modern submarine has placed new demands on ship personnel and has become a subject of increasing concern to people responsible for the selection of training approaches and the design of training devices. The purpose of the study reported herein is to aid in the development of more effective methods of submarine casualty control training and to ensure correct simulated environment for future training.

The study consisted of a human factors engineering examination of submarine casualties to identify critical factors in casualty control and emergency procedures, to determine emergency procedure skill behaviors, and to indicate optimum means for training these skills. Additional study requirements consisted of developing functional trainer characteristics for casualty control trainers, simulation tradeoff considerations, and research into generalized training.

Primary study steps were to identify, define, and classify casualties. These steps provided a study baseline for determining submarine personnel casualty control responsibilities, skills, and knowledges. Utilization of those data enabled the investigators to define critical factors for casualty control and casualty training requirements.

Subsequently, a three-step training methods analysis was performed leading to the determination of the required functional characteristics of new training devices: first, define and determine objectives for basic, intermediate/refresher, and advanced training levels; second, define and discuss alternate training approaches, including classroom aids, films, demonstration trainers, procedural trainers, generalized dynamic trainers, and high-fidelity dynamic trainers; third, the actual methods analysis, correlate the casualty control training requirements with training levels and methods.

Research into the feasibility of basic generalized casualty control training included investigations regarding training on different levels, behavior skills to be trained, present personnel ship assignment and training practices, and considerable study into transfer of training research.

The study confirmed previous research and opinions that plane failures and flooding are the most critical of the casualties to be trained. Critical factors for recovery and skill behaviors to be trained were identified. These factors (1) emphasize immediate detection and automatized (immediate) emergency response; add as critical requirements for team training, judgments by the Officer of the Deck (OOD) and the upgrading of enlisted men to stand Diving Officer (DO) and Ballast Control Panel (BCP) Watches; (3) emphasize the need for programs of standardized alternate recovery actions and guidelines related to depth and speed bands; and (4) emphasize the need for adjustment of recovery action to operational requirements, such as the tactical situation and concealment by noiseless submerged running for as long as possible.

ABSTRACT

The recommendations that grew out of the study include, first, those generated in direct response to the study requirements and, second, those developed for other related needs, which were suggested during the course of the study. The recommendations in the first group include characteristics of high-fidelity dynamic ship control trainers for SSN's and SSBN's, respectively; a flooding demonstration trainer; a communications trainer; and a BCP emergency procedures trainer. The recommendations in the second group include the use of basic generalized dynamic ship control trainers (for example, Device 21B56A), a training course for upgrading nonline officers and enlisted men to stand the DO watch, the establishment of standardized casualty recovery procedures and guidelines (including standardized flooding classification and reaction), the development of recoverability data for less than "worst case" casualties, and an additional study effort on damage control training approaches.

FOREWORD

This document presents an intensive analysis of submarine casualty and emergency problems and control procedures. It identifies and examines the critical factors in terms of (1) responsiveness to training, (2) optimum means for developing necessary skills, (3) levels of realism needed to ensure adequate transfer from simulated to operational tasks, and (4) potential for generalized approaches covering a variety of ships for basic, intermediate, and advanced training. The data and information were assembled from sources knowledgeable in the diverse aspects of submarine emergencies and represent advanced documentation, inquiry, and judgment.

The study was a joint human factors and engineering effort covering the behaviors involved and the equipment proposed for training. The recommendations for approaches and devices embody the global aspect of effective skill attainment. Hopefully, submarine officers and crews will further benefit by scanning the compendium of data incorporated in the body and appendixes of the report.

At the outset it was recognized that casualty control could be differentiated from damage control for purposes of study priority, but that the two are interrelated. The next phase of this research will deal with damage control, with particular emphasis on the requirements for training in flooding emergencies.

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RECOMMENDATIONS

The following recommendations have resulted from the submarine casualty control training study:

1. Advanced casualty control team trainer characteristics are presented that include characteristics of previous trainers with additions for effective casualty control training. These characteristics should be incorporated in new trainers. New recommended characteristics have been imposed on the hydrodynamic equations, ship system's simulation, and physical layout of future casualty-control trainers. Specifically included are economical malfunction simulation techniques, collision impacts, incorporation of an OOD trainee position, removal of the operator's console from the platform, simulation of an AMC system, and a capability for scoring and providing students with an objective knowledge of the results by utilizing event counters, analog recording equipment, and closed-circuit television (detailed discussion is given in Section V, Subsection One).

2. Several new trainers and trainer types are recommended, as follows:

   a. Additional ship control trainers are needed for both SSN and SSBN classes because of present and future personnel utilization demands. These trainers should include the casualty trainer characteristics identified in this study. (A rationale is presented in Section V of this report.)

   b. General emergency demonstration trainers are specifically needed for flooding recognition and of atmosphere contaminants. Flooding recognition training should be provided, using the "outside-in" trainer to allow trainee adaptation to high-pressure flooding effects and provide a baseline for judgment of flooding rates by showing scaled values of flooding. A supplementary justification for such a device would be its value as a research tool. (See Section V, Subsection Two, Item 4.)

   c. Concurrent with all casualties is a training requirement to provide communications training. A communication trainer is recommended for procedural training, under normal and adverse conditions, in all ship communication systems. (See Section V, Subsection Three, Item 3.)

   d. The functions of the ballast control panel operator (BCPO) are not trained in Submarine

RECOMMENDATIONS

School. Yet these functions are vital to ship recovery and casualty prevention. The BCPO needs training in basic operating procedures and in the handling of system malfunctions. The latter includes the identification of malfunctions, determination of systems affected, and isolation/corrective action by local watchstanders under the BCPO's direction. Ballast control panel operator training is recommended to satisfy these requirements. Because of ship class differences (panel and system arrangements) separate trainers and courses are needed for SSBN's and SSN's.

e. Generalized basic casualty control training is feasible and desirable. This conclusion follows in part from the nature of basic training itself, practical considerations regarding time of schooling, and ship assignment. It must be emphasized that effective casualty control depends on proficiency under normal conditions. The generalized trainer at this level consists of only the minimum of simulator fidelity to introduce enlisted men and junior officers to basic ship control problems (including demonstration of casualty effects, recoverability factors, and the effects of personnel reactions). (See Section IV, Subsection One, Item 4, and Section V, Subsection Four.)

3. Improved training of diving officers (DO's) (upgrading of nonline officers and enlisted men) is recommended. Since many ships employ nonline officers and senior petty officers as diving officers, effective casualty control demands that these men have a thorough grasp of principles governing trim control and analysis, the equilibrium polygon, and recoverability data. Furthermore, any officer who stands watch as DO with its inherent responsibility should have a ready means of refresher training. Such training should be provided in specialized course material, including films and lectures covering normal control functions, casualty effects, and the effects of recovery factors on ship control. These training courses should be provided at shore base facilities where SSBN crews undergo off-duty training cycles and SSN class ships undergo overhaul and upkeep cycles. To be most effective, training courses should be differentiated as to class of ship in the final phases of the course. Ship backup materials, that is, classroom aids, films, etc. should be prepared for each class of ship (Section V, Subsection Three, Item 4).

4. To facilitate training and effectiveness in dealing with casualties, standardized casualty/emergency recovery procedures and guidelines should be promulgated throughout the operating Submarine Commands. Items for

RECOMMENDATIONS

consideration include (1) flooding definition and classification criteria, (2) recovery actions and sequences as related to casualties at operating bands of depth and speed, and (3) allocation of specific responsibilities among members of the ship control party. (See Section V, Subsection Two, Items 1 and 4.) Operator trainer manuals should be included to ensure standardization of training and to ensure maximum trainer use.

5. Research data should be developed for ship responses to less than catastrophic hazards and for recovery actions that are graduated in degrees to suit the degree of seriousness of the casualty and the general situation, including the tactical situation and status of ship systems such as main ballast tanks (MBT) air banks and vents and propulsion. (See Section V, Subsection Two, Item 1.)

6. Additional work should be done in the following areas:

   a. Submarine damage control techniques should be evaluated to determine critical factors in damage control, and the best approaches for training these skills. Flooding problems, such as recognition, definition and isolation should be examined in detail. (See Section V, Subsection Two, Item 4.)

   b. Associated with the damage control training investigation is the problem of identification of optimum classroom aids to provide this training. For example, isolation training is considered highly desirable, but at present classroom training is limited to descriptions of general systems operation and malfunctions. A damage control study is recommended to identify common modes of specific failures and problem solutions. This study would combine training requirements and specify optimum classroom damage control training devices.

   c. Simulation techniques presently used for ship control trainers should be reassessed to include developing a criterion for computer choice and utilization. Determination of an optimum computer configuration should include identification of tradeoffs involved in choosing general purpose computers over special-purpose and tradeoffs between state-of-the-art analog computers, digital computers, and hybrid computers. Trainer utilization, especially that involving analog computers, should be examined to determine feasibility of session banding to reduce hardware requirements, increase effectiveness, and reduce cost. (See Section V, Subsection One.)

ACKNOWLEDGEMENTS

The research reported in this study could not have been accomplished without the consideration and wholehearted cooperation of many submarine agencies and individuals. These sources provided a background of data and experience that the investigators used in the study. However, the contributors acknowledged here are in no way to be held responsible for the opinions and findings expressed by the investigators.

Sincere and positive gratitude is extended to:

1. The FBM training centers at New London, Charleston, and Pearl Harbor for providing information concerning personnel and personnel capabilities, trainer characteristics, limitations, and curricula.
2. The New London Submarine School for providing data on present casualty control training.
3. The Pearl Harbor Submarine Training Center for making available data on additional training devices.
4. The Submarine Safety Center, New London, for providing extensive data and concepts on casualties, criticality, statistical data, collision data, access to the results of its studies, and valuable concepts on approach.

Special recognition is given to LCDR R. D. Griffiths (Instructor, Tactical Division) (INSTTACTDIV) at the U. S. Naval Submarine School, New London, for his genuine interest in study problems, as demonstrated by his assistance in making available a wealth of information on casualty control training and trainers, course curricula, concepts on recoverability, training effectiveness data in recovery procedures, and assistance in scoping the study.

Gratitude is also extended to the Commanding Officers of the USS Von Steuben [SSB(N) 632], the USS Nathanael Green [SSB(N) 636], the USS Shark [SS(N) 591], and the USS Barb [SS(N) 596] for extending to personnel the courtesy of shipboard visits and, thus, the opportunity to view operational equipment; and also for their willingness to discuss ship configurations and modifications, watchstanding duties, training practices, and the experience and training levels of their personnel.

Additional information on ship practices, operational safety limits, personnel training, experience, and attitudes about casualty recovery effects and training was obtained from a questionnaire submitted to senior officers of off-duty crews of many ships of the Atlantic and Pacific Fleets, as well as senior officers at the training facilities at Charleston and Pearl Harbor. Because of the number of people involved, personal acknowledgement cannot be made to individuals, but thanks is expressed to all those who participated in the questionnaire program.

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INTRODUCTION

1. GENERAL

The deep-diving, fast, and highly maneuverable nuclear-powered submarine presents problems of emergency and casualty control significantly beyond that of earlier submarines. The factor of time, among others, has become more critical, and in certain emergencies the command decision assumes an all or none character. The loss of the USS Thresher underlined the need for intensive and continuous training in the effects and appropriate recovery actions of a wide variety of malfunctions, casualties, and emergencies. The training must also provide the officers and men of the submarine forces with the opportunity and equipment to learn their ships' capabilities and limitations and to exercise their sensory, motor, and decision-making functions under controlled conditions. It is apparent that training actual operational hazards must be avoided, and that the effective training situations must be provided in a simulated environment.

Shortly after the sinking of the USS Thresher the Navy Department formed a Submarine Safety Group, which is coordinated through the submarine design section of BuShips (Code 525). One of the many tasks to be investigated was the problem of casualty control training. The solutions to the problem have been and are being investigated and examined by both agencies within the Navy Department and others under contract.

However, the question, "What is the optimum way to conduct submarine casualty control training?" persists. In March 1965, an outline was prepared to study the subject, submarine casualty control training, in depth. The investigation of five questions was required:

1. What are the critical factors in casualty control and emergency procedures? Which of these situations should be considered for training?
2. What are the skill behaviors that have to be developed to ensure adequate performance under emergency conditions?
3. What is the optimum means for training these skills?
4. What levels of simulation will be needed to ensure the best tradeoff between realism and return for each situation or parameter identified?
5. Can a generalized approach be used to provide basic casualty control training for crews in a variety of ships, or must individual trainers be developed for each class of submarine?

SECTION I - INTRODUCTION

In addition to answering these five questions it was necessary to survey specific existing ship control trainers and uses to determine applicability and develop background information on current and future casualty control training needs for use in devising and evaluating alternative training approaches.

2. CASUALTY CONTROL TRAINING STUDY

The study program was conducted in accordance with the objectives of Study, Submarine Casualty Control Training, as defined in U. S. Naval Training Device Center (USNTDC) Study Outline 552-171, 2 March 1965, Project 7878-2. Five main areas were covered, as follows:

1. Casualty identification and classification
2. Casualty sequence and task identification
3. Training requirements analysis
4. Training methods analysis
5. Simulation requirements analysis

These five areas require extensive interaction between human factors and simulation engineering personnel to determine both the human factors and engineering solutions to the submarine casualty control training problem. Because of this interaction, these five areas have been integrated in the study and this report. The report is organized according to USNTDC direction, as follows:

I - Introduction

II - Statement of the Problem

III - Method of Procedure

IV - Results

V - Discussion

VI - Conclusions

Jointly, the "Methods of Procedure" (Section III), and "Results" (Section IV), present the approach to the casualty-control training problem solution. Data collected by analysis of documentation, interviews with Submarine Command personnel, and visits aboard ships (see Appendix A) have been applied to the five study areas outlined above. The results have been discussed and detailed data and opinions collated to form answers for the basic questions of the original study outline. In the "Discussion" (Section V) a further consideration has been given to matters broad in scope (such as feasibility of generalized training) as well as to simulation background material and alternate training approaches. In addition, consideration is given to matters of casualty and damage control

SECTION I - INTRODUCTION

related to submarine emergencies and safety, which fall beyond the scope of the present study and represent the basis for additional study.

SECTION II
STATEMENT OF THE PROBLEM

The broad question of this study is what type of training and training requirements are optimum for submarine casualty control. Increased systems complexity, together with the tremendous expansion in the operating capabilities of the modern, high-performance nuclear-powered submarine, have multiplied the problems confronting the officers and crews of these submarines. In the realm of casualty control, the problems are presumably more severe for two primary reasons. First, less time is available in which to recognize and then to implement effective control of the casualty because of the increased speeds and depths at which these submarines can operate. Secondly, the overall level of submarine-oriented experience is lower (because of personnel rotation and advancement) in relationship to the complexities of the submarine systems.

Inasmuch as future submarines will provide an even greater increase in performance and integrated systems complexity, the problems associated with effective casualty control will also multiply. The training problem takes on new dimensions in view of other measures that have been resolved to improve submarine safety. One of these measures is the modification of the submarine to include remote control panels, manual override systems, and special emergency systems.[a] As a result, alternate and backup modes of emergency operation must be learned. Additional submarine system knowledge must also be learned to appreciate cross-coupling effects. Another measure to be considered is the accumulation of model basin test data and computer data that will establish recoverability effects data as a function of the nature of casualties and recovery actions. The implications of these data for procedures, decisions, and actions must also be acquired through training.

The scope of casualties and casualty control procedures to be considered was left an open question to be defined by the investigators. This question, in and of itself, implied that a survey was needed of almost all casualties, followed by a reduction, on rational grounds, of the casualty and/or casualty effects to be considered. In addition, the procedures for training had to be specified. Hence, the question of scope, although normally a part of the study planning phase, became a major and the initial problem for investigation.

Beyond the question of scope, the problem for study was to generate

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[a]For example research data indicate that disastrous consequences may result from the use of emergency blow when the ship is operating outside a slow, shallow-depth operating envelope.

SECTION II - STATEMENT OF THE PROBLEM

successive phases of information necessary to identify criteria for training simulation. This involved identifying critical factors for casualty recovery, the critical factors and collateral skill/knowledge requirements necessary to train personnel, the method of training personnel, and the simulation requirements. In addition, the problem involved determining the feasibility of generalized basic casualty control training and the feasibility of adding casualty control features to existing trainers.

SECTION III
METHOD OF PROCEDURE

1. APPROACH

The method of procedure describes the systematic approach, diagramed in Figure 1, that was used to solve the casualty control training problem. The identification and classification of casualties began as data in the form of documentation, correspondence, observations, and personnel interviews became available. Results of this effort constituted an overall baseline against which subsequent phases of the casualty control sequences and tasks, training requirements, training approaches, and functional simulation requirements were determined.

At this point in the study, casualty control groups were selected on the basis of priorities assigned in the classification scheme and the collation of behavioral elements from the casualty sequence/task identification. Subsequently, the training requirements analysis was determined; general watchstanders' collateral responsibilities, critical factors for recovery, and skill/knowledge training requirements were determined. Then the training requirements were identified and grouped as functional training units. For each of the latter, available types of training approaches were evaluated for different training phases. In the process of determining the desirable type of training, various training aids and devices were considered, which were later grossly scrutinized as to characteristics, cost versus effectiveness, and basic justification. The combined results of this approach are discussed in Section IV. The study areas and interactions between human factors simulation engineering and existing training hardware are illustrated in Figure 1.

2. CASUALTY CONTROL DEFINITION

For purposes of this study, casualty control is based on the concept of a safe operating envelope. From this viewpoint a casualty or emergency is a condition or event that will have a significant effect on a submarine's safe submerged operating capability. The effect may be direct in that if the submarine is not brought to the surface, or a safe depth and speed, it will be lost. Or the effect may be indirect, as in a general emergency, such as a fire or atmospheric contamination, when the submarine must be brought near the surface to provide habitable conditions for the personnel. Conditions that have these effects were assigned priority for study. Other types of failures or problems that could be isolated as system malfunctions, and submarine/personnel safety assured, without affecting the submarine's operating envelope were first listed as casualties, but upon identification were relegated to serious considerations

SECTION III - METHOD OF PROCEDURE

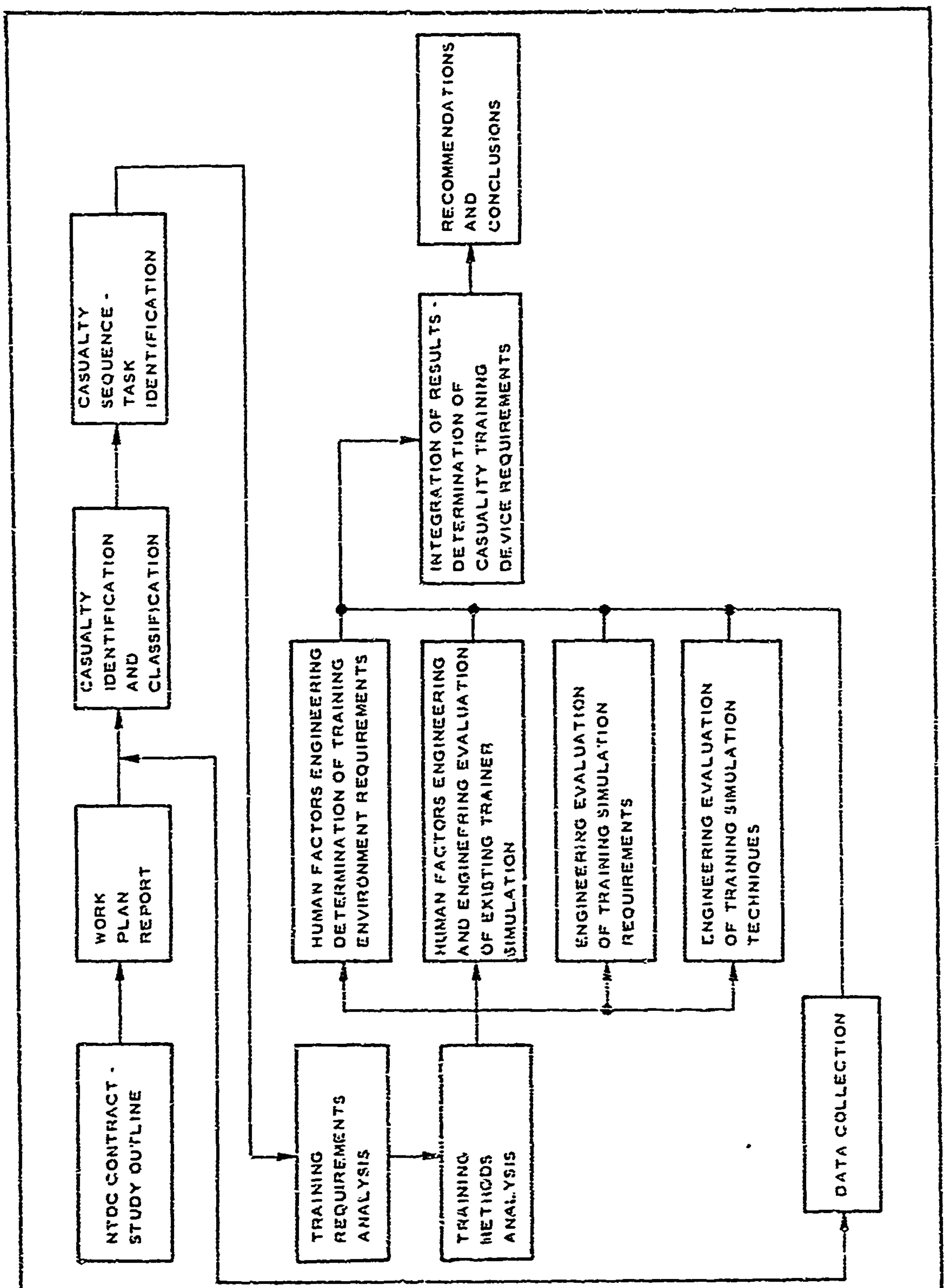

Figure 1 - Casualty Control Training Study - Procedural Diagram

SECTION III - METHOD OF PROCEDURE

only when taken in combination with the critical casualties.

As contrasted with damage control, this study dealt with the immediate detection, decisions, and actions required to maintain the submarine's safety in the face of a potential or existing casualty. With the exception of limited immediate isolation, damage control was not considered.

3. DATA COLLECTION

Data were collected from documentation, command visits, shipboard inspection and crew interviews, and standardized interviews of off-duty SSBN crews. Data sources are identified in Appendix A. The documentation that was collected covered five main areas of endeavor. These are

1. Information about ship systems and operating practices, including the Ship's Organization and Regulations Manuals (SORM's), Ship's Information Books (SIB's), and ship qualification guides
2. Information about casualties, effects, and recoverability factors, including collections of casualty records, the SSB(N) 616 damage control book, recoverability studies and control information, and submarine safety programs, guides, and instructions
3. Training device characteristics, including training capability evaluations, trainer operating, and maintenance instructions, and casualty simulation modifications
4. Training programs, curricula, and guidelines
5. Training research data covering vigilance, scanning, discrimination, decision making, and perceptual-motor tasks, including procedures and tracking tasks

Command visits included trips to Bureau of Ships (BuShips); Bureau of Personnel (BuPers); Submarine School, New London, Connecticut; Fleet Ballistic Missile (FBM) training facilities; Submarine Safety Center (SUBSAFCEN); Commander Submarine Force, U. S. Atlantic Fleet.(COMSUBLANT); and Commander Submarine Force, U. S. Pacific Fleet (COMSUBPAC).

Shipboard inspections and crew interviews were conducted on board two 627 class (SSBN) submarines and two (SSN) submarines.

Standardized interviews of off-duty SSBN crews of both COMSUBLANT and COMSUBPAC were accomplished using a formalized questionnaire.

SECTION IV
RESULTS

Subsection One
Casualty Identification and Classification

Early in the study, a very complete casualty classification scheme was completed that was based on a failure mode analysis (the results are shown in Appendix B). This classification scheme was determined, by the investigators' examination, to be too detailed for a systematic human factors approach to the study. For example, a separate consideration was made of "stern planes fail on full dive" and "stern planes fail on 0- to 20-deg dive." After examination, it was decided to group these into one class called "stern planes fail on dive." Consequently, a second classification scheme was devised that was behavior oriented (the results of this scheme are shown in Appendix C). Nonetheless the first detailed classification scheme (failure mode analysis) is included in this report since it provided useful base data for the later analyses.

The behavior-oriented classification (Appendix C) is based on an analysis of basic submarine officer training and experience, as well as extensive documentation and human factors engineering analysis. The classification of casualties as defined in Appendix C is based on a scheme of class, subclass, and sub-subclass. In order of priority, the main classes of casualties are:

1. Class I - Ship Command and Control Systems
2. Class II - General Emergencies (fire, flooding, collision, etc.)
3. Class III - Power Plant Casualty Effect

Each of these classes is then subdivided into the sub and sub-subclasses. An example of this classification scheme is the identification of SHIP COMMAND AND CONTROL as the major class of casualty or malfunction, STERN PLANE CASUALTIES as the subclass casualty, and Fail on Dive as the sub-subclass casualty. This scheme provides a baseline of casualties and malfunctions to be considered as candidate situations for casualty control training.

In order to determine which of the malfunction/casualty/emergency situations should be considered for the training requirements analysis, a method had to be devised for establishing the relative criticality of each abnormal situation as identified in the preceding paragraph. The resultant method used two factors on which to base relative criticality:

1. What is the effect on the submarine if no recovery/corrective/compensatory action is taken?
2. What degree of ship control action is required to recover from the malfunction/casualty/emergency?

The casualty criticalities are based on data published in submarine recoverability studies, damage control books, and personnel interviews (as delineated in Appendix C).

The ratings of criticality are given for each malfunction/casualty/-emergency situation in Appendix C. Ratings of one to five represent the consensus of the investigators' judgments. Criteria for assignment are:

1. Immediately commence emergency main ballast tank blow to surface or periscope depth to control casualty and/or reduce its severity.
2. Immediately commence normal main ballast tank blow and conduct normal surface or come to periscope depth or another safe depth, less than 200 ft, to control casualty and/or reduce its severity.
3. Deliberate ship control action may be required to ensure safe ship operations. Restore system functions immediately.
4. Ship control action may not be immediately required. Restore system functions immediately.
5. Continue operations. Immediate action is not required.

It was found that single valued ratings could not be assigned at the sub-subclass level of casualties. Hence, an attempt was made to determine the severity of the casualty on the basis of the mode of failure. (In other words, criticality for recovery varies as a function of the mode of failure and degree of complexity of failure along with the tactical submarine situation.) The multivalued degrees of criticality and the underlying information that served as the basis for assignment, therefore, acted as weight factors for the casualty-control-task groupings utilized during the subsequent casualty sequence and analysis of task-identification and training requirements.

SECTION IV
RESULTS

Subsection Two

Casualty Sequence and Task Identification

1. GENERAL

The data generated as a result of the casualty sequence and task identification are organized by class of casualty. They present the personnel activities required from initial detection until effective control is achieved. The analyses are psychologically oriented so that the data highlight the critical factors, from the training standpoint, in casualty control procedures. The results of the casualty sequence and task identification are presented in Appendix D.

The first step in the combined sequence and task analysis was to choose the casualties from the revised classification (Appendix C) scheme so as to encompass common behavior elements within each class. The results of this choice are reflected in the following list of casualties:

1. Ship command and control casualties
   - a. Stern planes fail on dive
   - b. Stern planes fail on rise
   - c. Fair water planes fail on dive
   - d. Fair water planes fail on rise
   - e. Rudder failure
2. General emergencies
   - a. Fire
     - (1) Operations, missile, and bow compartments
     - (2) AMR (auxiliary machinery room) No. 1 and 2 (or AMS, auxiliary machinery space and air-regeneration room in SSN ships), and reactor compartment
     - (3) Engine compartment
   - b. Flooding
     - (1) Bow compartment
     - (2) Operations and missile compartment
     - (3) AMR No. 2 (or AMS) and engine compartment

(4) AMR No. 1 (or air regeneration room) and reactor compartment

c. Atmospheric contamination

d. Surface collision

e. Submerged collision

Some of the failures identified in Appendix C were not analyzed. For this reason, individual casualty sequence identifications were not made. The failures that were not analyzed were treated as malfunctions. The reason was that - in the opinion of the investigators and as indicated by the assigned criticality ratings - none of these failures would acquire the significance on proportions of a casualty when occurring alone. The failures excluded from a separate formal analysis were the electrical, mechanical, or indicator failures associated with:

1. Normal and Emergency MBT blow system
2. Variable ballast tank systems
3. Trim and drain system
4. Snorkel system (excluding flooding casualties analyzed as part of the overall general emergency)
5. Mast systems
6. Interior communications system

A malfunction within one of these systems could acquire casualty or emergency proportions when combined with an existing malfunction, casualty, or emergency. The significance of combined casualties was recognized and alternate procedures, to correct or control the original failure when a second failure occurred, were introduced in the casualty sequence and task analysis. Coverage of crew reaction to failures, excluded from a separate formal analysis, was included in the training requirements analysis. This analysis identified the crew position responsibilities and critical factors for casualty control requirements, as well as skills and knowledges to be trained. It is significant to note that these systems, except the drain system on current SSN's, are monitored controlled and/or operated by the BCPO.

The recovery action for each of the casualties analyzed followed a common sequence as anticipated in the work plan report. The results are summarized below in Items 2 through 7.

2. CASUALTY RECOGNITION

The ship control center receives information of a casualty by communications and alarms from the engineering officer of the watch

(EOOW) or local watchstanders, from indications on the diving control station panel or BCP, or from direct sensation of the ship behavior. Typically, the ship control party (helmsman, stern planesman, BCPO, DO, and OOD) react to deviations from a baseline composed of speed, depth, depth rate, trim angle, course, turn rate, power plant status, and control power status taking due account of navigational factors, the tactical situation, and undetected submerged operation that is essential to the mission objectives. Thus, monitoring and cross-checking these indications and reports are essential tasks for effective casualty control, along with observing safe limits such as minimum and maximum speeds at deep depth, maximum speeds when masts are raised near the surface, maximum ship angles, and minimization of plane angles during normal running. This part of the analysis is, therefore, a summary of the crucial casualty recognition tasks for the ship control party as a group. As indicated in the preceding paragraph, the BCPO must also react to those system failures that are not critical as long as they occur alone but would be critical if they occurred in combination with flooding or stern plane casualties. These system failures include the main ballast tank blow and vents, trim and drain system, hydraulic system, and interior communications. In each case, the failure is shown by panel indications, or the lack thereof, in response to manual control activation. The recognition problem is one of proper monitoring (i.e., proper indicator scanning and indicator/ship response indication), determining mode of failure, and determining status of systems essential for recovery such as MBT blow, hydraulics, and propulsion. The local watchstanders' casualty recognition task will involve (1) identifying the nature and location of flooding, type of fire, and type of toxic gas and (2) detecting various equipment malfunctions that may detrimentally affect ship control or develop into a general emergency.

3. DECISION-MAKING

Decision-making involves the evaluation of the ship's current status and capability, the assessment of the problem (including tactical and navigational factors and mission objectives), and the selection of a course of action. In matters affecting ship safety the OOD and DO should always be involved. Speed, depth, and attitude are basic, as are the tactical situation, navigational factors, and mission objectives. Crew capability, particularly the skill of the helmsman/-planesman and chief of the watch (COW), is very significant. Decision-making must also include the utilization of the recoverability data and the consideration of follow-on effects of possible corrective actions. These include both desirable and undesirable consequences, such as broaching or turbulent ship motion if emergency blow is not used with discretion.

In circumstances where a system or specific equipment is concerned, the individual watchstander must make a quick decision as

to the location and nature of the casualty. The watchstander must recall the immediate local action required. This will include notification of the appropriate control station; isolation of the affected equipment, system, and compartment; and execution of the emergency compartment bill.

The BCPO decision is particularly critical. His ability to identify the correct method of overcoming a control failure, such as MBT blow, may well determine whether the ship will be saved. One other decision maker of prime importance is the EOOW who must ensure performance of the general emergency and casualty control bill in engineering spaces and must line up the power plant for maximum reliable operation. Specific training of the EOOW is not within the scope of this study report.

4. CORRECTIVE ACTION

Action to correct or control the casualty situations were formulated generally for worst case failures. This action was cited as the "basic sequence" and was selected to be compatible with recoverability research and recommendations. Alternative courses of action were also identified. These alternatives were cited to show possible variations in casualty control as a function of special situations and desirability of avoiding unnecessary risk or compromise to the mission. One of the main points made clear by the task analysis is the criticality of immediate reaction to flooding and stern plane fail on dive. Another critical point not presently appreciated by the consensus of operating personnel is the formal recognition of the need for differentially responding to casualties to fit the situation - severity of casualty and consequences of corrective actions. For example, all out recovery action to a problem of moderate severity may in fact lead to a more disastrous casualty, such as collision.

5. INFORMATION FLOW

In most casualties, communication of the casualty situation is the first response of the watchstander. The primary exception is simple failures, such as control mode or indicator failures, where the operator switches to the emergency mode and then passes the word. Generally the watchstander communicates with the control center as quickly as possible, and the appropriate alarm is sounded. Doctrine on the communication sequence varies between SSN and SSBN, among ships, and among casualties. Also, depending on the compartment in which the watchstander discovers the failure, word may be passed directly to control or via maneuvering and the launch control station when the casualty is discovered by engineering or weapons watchstanders.

6. FOLLOWUP ACTION/FEEDBACK

An evaluation was made of the means of assessing progress in the control of an emergency, and the follow-on corrective procedures were implemented. The casualty control is considered complete when the appropriate decisions have been made and the necessary immediate corrective action has been taken to return the submarine to its safe operating envelope. Maintenance of the safe operating envelope may require additional follow-up action; for example the danger of broaching or collision while recovering from a casualty, such as flooding, must be averted. It may also require limitation of action; for example, emergency blow may need to be time-limited, depending on depth, speed, and rate of flooding, to avoid risk of broaching or uncontrollable roll.

7. ADDITIONAL CONSIDERATIONS, CASUALTY, SEQUENCE, AND TASK IDENTIFICATION

Before proceeding to the training requirements analysis (Section IV, Subsection Three), certain considerations and conclusions were reached based on the casualty classification scheme and the sequence and task analysis. Upon examination of the casualty sequence data, it was apparent that extensive areas of similarity exist among control procedures for different casualties. The casualty recognition, information flow, and to some extent the decision-making procedures, are essentially the same for stern planes (fail on rise or dive), for fairwater planes (fail on rise or dive), and for rudder casualties. The important differences lie in the person detecting the failure and the alternate courses of action available to counteract its effect. The sequence analysis also indicates similarities in the flooding control procedures insofar as they effect the ships control party. Again the differences appear in the watchstander detecting the flooding and the alternate courses of actions available. The similarity of common behavior elements indicates that the revised classification scheme (Appendix C) results in an economical grouping of major casualties. This classification scheme was also of value because it provided information for use in the sequence and task analysis. From this information, the function to be performed by different watchstander personnel in controlling a casualty could be discerned by cross referencing the mode of failure to its treatment in applicable documentation (SORM, SIB, etc.). It is also significant to note that the attempt to assign degrees of criticality to the respective causes of a casualty did not adequately define the severity of the casualty in all circumstances. For example, a system indicator failure does not of itself seriously endanger the safety of the ship. But if the operator does not detect this failure for what it really is, his excessive action may endanger the ship. For this reason a consultative approach to the determination of critical factors was applied. The approach taken was to base the initial selection of critical training situations on the general

consensus of experts: submarine engineers, subsafety experts, and ship personnel. On this basis, the following statements and groupings can be made about the seriousness of casualties relative to ship control training.

The first and most hazardous casualties are flooding at depth and stern planes fail on dive at high speed or deep depth. All parameters governing recovery (including correct/incorrect operation of MBT blow, hydraulics, propulsion, interior communications, and trim/variable ballast) and the most effective measures for recovery from these casualties need to be emphasized in shore-based training. Recognition of serious flooding, as differing from leaking and flooding-depth-speed-trim angle interactions, must also be adequately treated. Some of the parameters contributing to criticality of the casualty are the distinction between a serious mechanical stern plane failure and an indication or control mode failure; differences in the implication of a failure for near surface operation-vs-test depth operation; and the seriousness of failure at high speed-vs-hovering speed.

A second grouping of casualties - fire, atmospheric contamination, steam leaks, failure of hydraulic flex lines, and moderate flooding - can usually be combated directly by damage control techniques and general emergency procedures, such as compartment isolation. Ship control action, usually indicated to permit emergency ventilation, can be taken deliberately. Drills in the latter aspect may be exercised aboard the ship. OOD judgment regarding the latter is seriously dependent upon recognition and reports by the man at the scene. However, this group of casualties is of sufficient criticality for the OOD training in decision-making that provision should be included in team exercises on ship control trainers.

A third grouping of casualties includes failures of stern plane on rise, fairwater planes, steering system, hovering system, and most power plant casualties. This group is not usually of immediate seriousness in that compensation by use of other normal systems is usually possible.

A fourth grouping of casualties, when considered individually, has been downgraded in the investigators' judgment to the status of malfunctions. Occurring by themselves, these casualties do not affect ship safety. Yet they involve the systems that are often the most vital for recovery from the first two casualty groups. The entire main ballast tank blow system falls in this group. The fairwater planes and steering system might also be grouped under this category. Other systems considered from this standpoint are the trim and drain system, negative tank system, interior communications systems, snorkel system, propulsion system, and the electrical plant.

Consideration of plane and rudder failures, fire, flooding, and

collision as encompassing all the major and critical casualties leads to the conclusion that all the sequences and tasks associated with these systems are critical to ship safety and recoverability. It was, therefore, this scheme of criticality, described earlier in Subsection One of Section IV, that provided the baseline for the next phase of the investigation - the training requirements analysis.

SECTION IV
RESULTS

Subsection Three
Training Requirements Analysis

1. GENERAL

The training requirements analysis was conducted in three steps. First, personnel responsibilities during normal and emergency situations were determined. Second, the critical factors for casualty control were determined by collating data from the sequence and task analysis (Appendix D). Finally, training requirements were determined by combining data from the first two steps.

2. PERSONNEL RESPONSIBILITIES

Crew position responsibilities for plane and rudder failures, fire, flooding, and collision are outlined in Appendix E. The crew positions covered include the local watchstanders, COW/BCPO, and helmsman/planesman. The responsibilities include actions that enable personnel to avert, reduce the severity of, or properly handle a casualty should it occur. This part of the analysis provided data for both normal and emergency crew responsibilities to aid in the determination of casualty training skills/knowledge requirements.

3. CRITICAL FACTORS AND SKILL/KNOWLEDGE REQUIREMENTS

The determination of critical factors for training and the skills and knowledge requirements for training was accomplished by the judicious extraction and collation of data from the personnel-responsibilities listing of Appendix E and the results of the critical sequence and task analysis in Appendix D. The critical factors and skills/knowledge requirements are provided in Table I for ship command and control; for fire reporting, isolation and extinguishing; for flooding recognition and isolation; for atmospheric contamination recognition and control; for propulsion casualty effects on ship control; and for electrical casualty control.

Throughout this study, it is recognized and indicated that the individual BCP malfunctions are not in themselves critical to recovery unless coupled with another more serious casualty. However, since the BCP is the nerve center and control point for most systems and is essential in recovery, and because personnel are not selected for this position during basic training, supplemental training is needed as senior personnel are upgraded to the BCP

watch. For these reasons, requirements were developed for training personnel to react to malfunctions of systems controlled and monitored at the BCP. The investigators found that requirements for BCP training could be adequately established by extracting data from the other group of critical factors and skills knowledge requirements.

TABLE I - CRITICAL FACTORS AND SKILLS,

Training category	Critical factors	
I. Ship command and control	1. Imm 'iate detection of plane or rudder casualty symptoms. 2. Rapid discrimination between indicator failure, electrohydraulic failure, and mechanical failure on diving panel or BCP. 3. Rapid corrective response implementing only action required to recover from casualty, minimizing effect on satisfaction of mission requirements, e.g.: (a) if depth indicator fails, use emergency indicator; (b) if normal hydraulic mode fails, operate in rate control; (c) if fairwater planes jam, compensate with stern planes; (d) if rudder jams, reduce ship speed and compensate for attitude change with planes. 4. Follow up ship control corrective action for stern planes fail on dive or flooding to achieve safe depth minimizing incompatibility with tactical situation. 5. Avoidance of confusion in interpretation of casualty symptoms by proper scanning and monitoring of depth, steering, speed, and BCP indications and by proper trim analysis and control. 6. Immediate recognition of failure of controls being used in ship recovery and use of alternative modes of activation: e.g., manual activation of pilot control valves for planes and emergency blow, lineup and use of local hydraulic valves for planes, depth control and steering using rate-control mode, and local MBT vent control. 7. Sound-powered phones manned for local control of vents, stern planes and rudder. 8. OOD receives current information on general emergencies, such as flooding and fire and power plant. 9. Immediate decision and initiation of emergency blow to surface or come to safe depth upon recognition of stern plane fail on dive or serious flooding. 10. Immediate decision and initiation of depth change including preparation to emergency ventilate as appropriate to fire, atmospheric contaminat...n, or radiation casualty. 11. Effective control team interaction and communications.	1. To ensure ors, contr trol. 2. To develop able indica 3. To develop normal aut action. Th normal shi 4. To develop ation, such (emergency 5. To ensure dicators, c angle, or l 6. To develop sponses fo 7. To develop rate contro 8. To develop alarms, an ventilation, 9. To develop indications and DO for 10. To develop tors as dep tions show 11. To develop to include e actions. 12. To develop 13. To develop effects of r envelope. 14. To exercis
II. Fire recognition, isolation, and reporting	1. Immediate sounding of alarm. 2. Rapid compartment isolation. 3. Rapid isolation of electrical equipment involved or of materials feeding fire. 4. Determination of type of fire and choice of proper type of fire extinguishing agent. 5. Accurate reporting of type and severity of fire. 6. Area of protective gear and emergency breathing apparatus. 7. Determination of need to emergency ventilate.	1. To ensure cation in al 2. To develop their assig 3. To develop tion of elec 4. To develop ing masks i 5. To develop

[a]No direct correlation exists between numbers assigned to items in middle and right-hand columns.

TORS AND SKILLS/KNOWLEDGE REQUIREMENTS

	Skills/knowledge*
ns. ydraulic	1 To ensure high degree of tracking capability by planesmen so that cues of malfunction from indicators, control system, or ship feel are not confounded with erratic or improper planes or depth control.
ired to of mis-	2. To develop in planesmen and DO's proper scanning habits and ability to shift attention among available indicators, thus avoiding mesmerization by one indicator or tunnel vision
e emer- ate in h stern nsate	3. To develop in planesmen and DO's capability to rapidly switch mental sets from one appropriate for normal automatic maneuvering control (AMC), or one-man control to one appropriate for emergency action. This includes prompt and discriminating reaction to alarms, abnormal indications, or abnormal ship motion
fail on atibility	4. To develop in planesmen and BCPO perceptual motor capability to shift to alternate modes of operation, such as rate control, manual overrides for emergency blow or plane control, and local (emergency) manual control of planes, rudder, and vents.
toms by d, and	5. To ensure in DO's ability to analyze and maintain trim control so that cues of malfunction from indicators, control system, or ship feel are not comfounded with heavy condition, down angle, up angle, or list due to improper or unknown trim.
n ship	6. To develop in planesmen ability to recognize, diagnose, and initiate appropriate corrective responses for stern plane, fairwater planes, and rudder casualties.
mer- planes,	7. To develop in DO's ability to recognize, diagnose, and direct corrective action for depth and depth rate control problems due to indications of stern planes, fairwater planes, or rudder casualties.
local stern	8 To develop in DO's ability to initiate ship control actions in response to general emergencies, alarms, and as directed by OOD. This includes emergency surface, depth change for emergency ventilation, and depth change to ordered depth
es, such	9. To develop in OOD's/conning officers ability to scan and monitor ship control indications and BCP indications and evaluate ship performance to detect abnormal ship status, to monitor BCP operator and DO for performance that is inconsistent with ship safety and tactical situation.
urface on dive	10. To develop in DO's and OOD's appreciation of safe operating envelope for ship combining such factors as depth, speed, buoyancy powerplant lineup, depth rate, and tactical situation. Demonstrations show relationship between initial conditions and seriousness of casualty effects.
, at-	11. To develop in DO's and OOD's understanding of various corrective actions and combinations thereof to include effect of alternate actions on recovery and limitations and implications of use of recovery actions.
	12. To develop in OOD's skill to initiate expeditiously proper casualty control procedures.
	13. To develop in stern planesmen, helmsman, BCPO, DO, and OOD skill in evaluating the progressive effects of recovery action and performance of follow-up action necessary to restore safe operating envelope.
	14 To exercise the control team in effective interaction and communications.
	1. To ensure all personnel have knowledge of nearest location of communications/alarms from any location in all levels of each compartment.
terials	2 To develop in all personnel knowledge of all combustibles or electrical sources of fire in any part of their assigned watch station.
fire	3. To develop in watchstanders knowledge of equipment arrangement, controls, and location for isolation of electrical equipment or combustible materials involved in a fire.
us.	4. To develop in all watchstanders knowledge of location of fire extinguishers, protective gear, breathing masks in all compartments.
	5. To develop in watchstanders ability to judge the severity of the fire.

ht-hand columns

TABLE I - CRITICAL FACTORS AND SKILLS/KNO

Training category	Critical factors	
III. Flooding recognition, isolation, and reporting	1. Immediacy of report. 2. Distinction among leakage, flooding, and/or emergency flooding. 3. Optimum lineup of affected systems to optimize recovery capability. 4. Time to isolate flooding. 5. Follow up watchstander's report.	1. To devel flooding, 2. To devel sources 3. To devel sources adjacent 4. To devel quick fix 5. To devel and of op 6. To devel electrica 7. To devel and locat ference b
IV. Atmospheric contamination recognition, isolation, and reporting	1. Detection and identification of toxic gas. 2. Locate and eliminate the source of toxic gas. 3. Isolate the affected compartment. 4. Implement emergency air revitalization or ventilation as appropriate. 5. Break out and don (if required) emergency breathing system (EBS) masks.	1. To develo formaldel hydrogen 2. To ensur watch ar 3. To teach 4. To develo emergenc
V. Propulsion casualty ship control effects	1. Immediate report of system status to control. 2. Lineup to minimize effects of flooding in main seawater (MSW) system. 3. Lineup to optimize propulsion acceleration-speed time for recovery from flooding.	1. To teach capability 2. To exerci casualtie
VI. Electrical casualty recognition, isolation, and reporting	1. Detection of impending or existing casualty by observation and knowledge of equipment. 2. Rapid e[illegible]ation of equipment function, level of isolation required, and personal ability to properly isolate. 3. Immediate decision to isolate and report, or report and isolate, on command.	1. To provid 2. To teach 3. To provid 4. To ensur
VII. Ships systems monitoring and control	None except as applicable items of I through VI above.	1. To detect 2. To know 3. To unders 4. To under 5. To repor 6. To direct 7. Local pe 8. Local wa operation 9. Local wa componen 10. Local pe direct co

*No direct correlation exists between numbers assigned to items in middle and right-hand columns.

AND SKILLS/KNOWLEDGE REQUIREMENTS (Continued)

	Skills/knowledge*
flooding. y capa-	1. To develop in all personnel the ability to recognize the various manifestations of high-pressure flooding, impingement, and vaporization.
	2. To develop in all qualified watchstanders knowledge of functional flow, hull openings, and other sources of flooding by physical location within compartments.
	3. To develop in all personnel knowledge and visual memory necessary to isolate or retard all possible sources of flooding. This applies to hull and backup stops as well as to subsafe control panels in adjacent compartments or levels within compartment.
	4. To develop in all personnel knowledge of what systems would be affected directly by flooding and quick fixes or improvisations to protect essential systems from flooding damage.
	5. To develop in watchstanders knowledge of system effects due to various flooding isolation actions and of optimum lineups to optimize residual ship control capability.
	6. To develop in watchstanders perceptual motor skill to isolate correctly affected systems, such as electrical units or circuits, and achieve the optimum lineup for continued ship recovery capability.
	7. To develop in watchstanders capability to properly communicate initial reports of flooding nature and location, plus amplifying status reports under conditions of stress, noise, and physical interference between the man and phone station.
	1. To develop in all hands a recognition of the following gases: acrolein, amine, ammonia, chlorine, formaldehyde, hydrogen chloride, monoethylamine, ozone, phosgene, selenium, sulfur dioxide, hydrogen fluoride.
approp-	2. To ensure all personnel know location of nearest communication box from any point within various watch areas.
	3. To teach location of materials and/or controls required for emergency revitalization.
tem	4. To develop requisite skills and knowledge including for BCPO and local personnel local actions for emergency ventilation.
(MSW)	1. To teach command and control officers who are not nuclear trained to properly evaluate residual capability of propulsion system upon report of system casualties and status.
or re-	2. To exercise control officers to solve ship control problems in combination with propulsion system casualties.
s and	1. To provide knowledge to all personnel of fundamental electrical malfunction indications.
re-	2. To teach all personnel location of electrical isolation boxes.
	3. To provide all hands understanding of equipment function in overall electrical system.
isolate,	4. To ensure correct communications by all hands with necessary personnel.
	1. To detect malfunctions based on local indication(s) at BCP.
	2. To know location of components controlled and/or operated from BCP.
	3. To understand effect of each malfunction on system(s) and ship operations.
	4 To understand and implement alternate methods or modes, if available, for accomplishing each task
	5. To report malfunctions to the OOD and DO or other superior officer.
	6. To direct local watchstanders to take corrective action via most direct communications system.
	7. Local personnel must detect malfunctions based on indications.
	8. Local watchstanders must understand how local component failure affects total system(s) and ship operations.
	9. Local watchstanders must have capability to shift to alternate modes of operation and/or isolate components/systems as directed by senior control stations or as required in a casualty situation.
	10. Local personnel must report changes in status to control or maneuvering as appropriate via most direct communication system.

*...-hand columns.

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SECTION IV
RESULTS

Subsection Four
Training Methods Analysis

1. BASIC CONSIDERATIONS

a. General

The Training Requirements Analysis developed those critical factors of casualty control for which training must be provided. The next step was to determine the methods by which these critical factors should be taught, but first it was necessary to consider the following subject areas as they relate to training submarine personnel:

1. Levels and locations of training
2. Objectives of training at each level
3. Previous personnel training and experience
4. Training cycles and opportunities for training

These are discussed in Items b through e, below. The specific training methods required are then discussed, beginning with Item 2, below.

b. Levels and Locations of Training

(1) General

Casualty control training can be taught profitably at the basic, intermediate, and advanced levels using present submarine facilities at the Basic Submarine School, New London, Conn.; Submarine Training Commands; and training facilities which should be provided for SSBN off-duty crews and SSN crews during overhaul and upkeep cycles at such bases as San Diego, Norfolk, and Key West. Also, training by examination and study and drills aboard ship are obviously mandatory.

Basic training is divided into two categories: (1) basic training, as provided at the Basic Submarine School, and (2) refresher/orientation and upgrading training, as provided at the Submarine Training Commands and Bases.

(2) Basic Casualty Control Training

The general objectives of basic casualty control training are to train personnel in the principles of submarine construction as related to mode of failure; systems and operation (characteristics, their failure modes, alternate operating modes, and generally their

interplay with casualty control) casualty causes; effects; basic recovery and/or control procedures; and the effects of recovery action on the ship operating envelope and systems. Personnel are not trained during basic training in the exact procedures, characteristics or operating methods of the particular submarine to which they will be assigned upon completing the course. This in itself would be a formidable task, since there are a number of different principal classes of submarines plus several subclasses within the principal classes.

Presently, it is understood that 31 hr are devoted to damage control training at the Submarine School. The subjects covered are organization, equipment characteristics, smoke room (demonstration), flooding demonstration (300 psi), flooding and stern plane casualty analysis, hull strength design (including sub safe features), fire, atmospheric contamination, collision, weapons casualties, welding and brazing, flex hoses, and electrical casualties.

(3) Orientation and Refresher Training

Upon completion of Basic Submarine School and assignment to a submarine, personnel should receive additional instruction in systems, arrangements, and procedures peculiar to that submarine. Personnel also will be required to "modify" some of the instructions received at the Basic Submarine School because of the differences between generalized submarines and the specific submarine. This will also apply to submariners being assigned to another class of submarine, since it is virtually impossible, regardless of experience level, to know the differences between all submarines.

The novice submariner, the qualified submariner being transferred from one class to another, and the qualified submariner returning from a nonoperating billet are faced with similar problems in that they must learn new systems, arrangements, characteristics, and procedures for their new submarine.

A submariner can be provided the necessary orientation or refresher training by reporting directly to his new submarine, the only method presently available, or be assigned to a submarine training command for a formal course of instruction of approximately one week.

The presently used method is advantageous in that personnel will be experienced in the actual ship environment with which they will be associated for approximately two years. This method has its disadvantage in that personnel will have very little prior casualty control skill or knowledge that is specific to their new assignment and will not be in a position to react properly even though they may be expected to do so. In addition, these personnel detract from the submarine's operational readiness and effectiveness, since experienced personnel will be more error prone due to the stress of a heavy work load and extra training duties while the new men are being qualified.

The second method (shore training) would be advantageous in that personnel would receive training in port while the submarine was undergoing patrol preparation and thus would report to the submarine with a greater degree of familiarity. This increased familiarity would reduce the time spent in an unproductive capacity by newly assigned personnel aboard the submarine and the time required by experienced personnel to stand port-starboard watches and to train inexperienced personnel. This course would familiarize personnel, with respect to a specific submarine class, in submerged and surfaced handling characteristics, operational capabilities and limitations, casualty control systems lineups, and casualty/emergency control and recovery procedures.

(4) Upgrading Training

Since the number of officer-type watches aboard a nuclear submarine has increased, with a very small increase in officer manning, it has been necessary aboard SSBN's to employ petty officers (PO's) in the capacity of Diving Officers of the Watch (DOOW). Although the submarine experience level of PO's is greater than that of the junior officers (JO's) whom they have replaced, they have not been given any formal training in principles of submarine operation and construction or practical operations in trim control and analysis, compensation, ship control casualty, and emergency control and recovery procedures. The present "under instruction" method of training PO's in the duties of a DOOW takes two to six months of standing at least two watches a day during underway periods.

During interviews with the JO's and PO's qualified to stand watch as DOOW's, neither group, in the opinion of the investigators, had a sufficient appreciation for the criticality of this position. Inadequate skill was in evidence in the DO/planesman interaction, in adequate understanding of the time factors in casualty recognition and control/recovery action, and in knowing the differences in correct control/recovery action sequences for casualties at different depths and speeds.

Several methods appear appropriate for training personnel for DOOW duties. The first and present method is to conduct the training aboard the submarine; the second would be a formal course of instruction at a submarine training facility. In either case, principal emphasis should be placed on submerged and casualty control training so that the prospective DOOW would be highly proficient in performing the functions and procedures for which he is responsible while the ship is operating at highly critical speeds, depths, etc.

Although the advantages and disadvantages of these methods are similar to those for the refresher training, one significant advantage of (and mandatory reason for) shore-based training is that a

group of prospective DOOW's could be brought together to work as a submarine control team, in a manner similar to that used in the basic officer's course. This teamwork would provide a better appreciation for the interrelationships and responsibilities of each member.

Through the judicious use of ship/casualty control trainers, personnel could reach a reasonably proficient level in approximately two weeks. Even though it would be a disadvantage to relieve the PO's of their extensive technical and administrative duties aboard ship for two weeks, much more time would be saved in the total qualification time per man. Finally, simulator training ashore is essential to provide prospective DOOW's experience in handling casualty situations into which the ship cannot be reasonably placed.

Another vital member of the ship control party for whom formal upgrading training is not provided is the BCPO. Although he has an adequate understanding of the basic operations of the individual systems controlled from the BCP, it is essential that he receive training at a shore-based facility in casualty detection, decisions, emergency lineups, and communications in which he cannot be exercised aboard ship. He should also receive training in the general functions of the COW and standby/backup DOOW functions.

(5) Intermediate Training

As defined herein, intermediate training should take place after the completion of basic/refresher training through the first few weeks of ship assignment during the SSBN off-duty cycle and during SSN overhauls and upkeep cycles. It should also include the first few weeks of assignment after shore duty or duty on another type of submarine, for example, diesel versus nuclear. The general objective would be to provide advanced individual task and elementary team training for all watchstanders associated with casualty control. Training should stress the learning, relearning, or "overlearning" of specific knowledge and skills necessary for the proper performance of a duty assignment aboard a particular ship. This should include systems interrelationship, systems operating and casualty control procedures, and elementary team training. Emphasis should be on the development of individual skills to such a degree that on detecting a casualty not only would an immediate reaction occur but such a reaction would be adapted to fit the overall situation, that is, operating envelope, tactics, navigational factors, and special instructions. This would require much more knowledge and/or skill than just knowing and/or carrying out the provisions/procedures of the ship emergency and compartment bills.

It is highly desirable to incorporate intermediate casualty control training as an augmentation of the training and qualification programs not strictly associated with casualty control. For example, to isolate the inrush of water it is necessary to know which valve

to close and the location of the valve or alternate (such as sub safe remote control panels) method of operation. It is also necessary to instruct personnel in evaluating the actual or potential severity of the flooding. This can be accomplished only when the man at the scene knows the equipment in the vicinity, effect on other systems, floodable volume of the compartment, and other pertinent variables. Also, advanced individual casualty control training can be accomplished only when the individual has experienced the sensible manifestations of different rates of flooding and can rely on his memory of the experience as an anchor point in subjectively scaling the rate of flooding.

(6) Advanced (Team) Training

Advanced training for some of the less critical submarine casualty control operations can take place aboard the submarine. However, drills in combating the more severe casualty situations cannot be allowed for reasons of personnel and ship safety. Severe effects due to inefficient handling of the casualty cannot be permitted. Casualty drills must be carried out within operating limits imposed by the SUBSAF program and patrol objectives. Casualties cannot be compounded, and the wide varieties of failure-mode situations which pose problems of judgment and discriminating actions cannot be presented to crews aboard ships. For effective advanced training, high-fidelity training devices are needed.

Training during this phase would stress learning by doing to gain the specific skills and the knowledge required to operate the ship proficiently, as well as stress the individual's position as a member of a team during normal and emergency operations. This would be accomplished by actually operating the simulated equipment and systems (including communications) involved through participation in a training program on an advanced, casualty-equipped, dynamic simulator.

As a member of the ship control party, the OOD is the single most important person as he must be continuously aware of the submarine's operational capabilities and limitations, of ship systems status (for example, power-plant lineup), the tactical environment, mission objectives, and navigation factors. He also must receive and evaluate all initial and amplifying casualty reports. He not only must make immediate and correct decisions as to the most appropriate ship/casualty control action to be taken but give (or delegate authority for) the necessary orders and commands to rectify the situation.

Although the OOD's authority and responsibilities have not changed much in modern submarines, the problems confronting him have increased significantly. Some of these problems are:

1. His experience level is generally lower than in the past.

2. Much less time is available to make correct decisions, because of the increased operational capabilities (depth and speed).

3. Systems are more complex to understand, operate, and evaluate, and he must supervise ship control - on a time-shared basis with other supervisors - of other systems of a highly technical nature that are vital to the ship's patrol objectives.

4. Experience and qualifications of other team members, upon whom he must rely for information and action, are generally lower than in the past; for example, DO's are not now trained in principles of ship operation.

Although the OOD's task loading has increased significantly, a program of training to qualify him better to cope with the more complex and critical casualties is minimal.

The present training is generally limited to that gained on a self-taught individual basis and in a few types of casualty drills that may be conducted aboard ship.

Since complex casualties, in which critical decisions are made by the OOD, cannot be realistically simulated from the standpoint of behavior requirements aboard the ship, and since these decisions are based on information received from other ship-control-party members, it is felt that the OOD should be trained along with and as a member of the ship control party, not as an instructional adviser and observer.

c. Objectives of Training at Each Level

(1) Basic Casualty Control Training

Basic casualty control training would be accomplished at the submarine school and should be given to all JO's and enlisted men. This training would cover the following as they relate to ship control and general emergencies:

1. Typical construction - hull shape(s), sizes, reinforcements, and openings with associated flooding manifestations

2. Functions and operating characteristics of systems - emergency modes of MBT blow, hydraulics, hovering (or negative tank) systems, etc.

3. Basic ship control - use and meaning of instruments, basic skill in positioning planes, AMC failure modes, fundamental control-display relationships, control modes, etc.

4. Principles of ship operations (officers only) - stability, trim analysis and control, and the equilibrium polygon
5. Control surface casualties - failure modes and effects
6. Recognition of visual indications, recognition of auditory alarms, knowledge and rudimentary skills in basic reactions to casualty indications
7. General emergencies - recognition, nature and effects, basic reactions, and alternatives
8. Casualty effects - modes of failure, nature and order of magnitude of effects, and relative effects of available corrective reactions; relationship of the preceding to ship control given different sets of initial conditions, such as depth, speed, and tactical situation
9. Communications - standard format, procedures, and critical implications of use during an emergency

An examination of these items will show that basic casualty skill and knowledge requirements are inextricably interwoven with normal operating requirements. Having the ship under effective control and exercising proper surveillance is essential for the prevention of casualties and effective reaction to casualties once they occur.

(2) Orientation and Refresher Training

Personnel should be required to attend an orientation and refresher training course prior to reporting to their assigned submarines. This training will be accomplished at a submarine training command for personnel having just graduated from basic submarine school and for all officers and enlisted men who are programmed for return to sea duty after a long period of shore duty or overhaul.

Training content to meet this requirement is the same as that specified for basic training except that the training will be shortened in time and oriented to the particular type of submarine to which the individual has been assigned.

In addition, as a general requirement, some of the training content from basic schooling needs to be presented periodically to active-duty personnel. As an example, personnel need to be exposed to a presentation of flooding effects at intervals of one to two years, not only to ensure proper adaptation and judgment, but also to present the results of up-to-date research. Another example of refresher

training is the retraining of ship control personnel in the proper use of diving panel indications (see Section V, Subsection Two, Item 3).

(3) Upgrading Training

Upgrading requirements occur with respect to senior enlisted personnel being trained as DO's and BCPO's. This training will be accomplished at a submarine training command facility. Both the DO's and BCPO's will need to be trained in the basic principles of submarine operation (for example, trim control and the equilibrium polygon), in construction, and in system interactions. The DO students will also be required to learn the basic procedures for command at the diving station. This will require practical operations in trim control, compensation, ship control, and casualty/emergency control and recovery procedures.

The BCPO students will be required to learn the basic procedures for operating the ballast control panel. This includes the capability to relate malfunctioning remote controls to local control at various watchstander positions aboard the ship.

(4) Intermediate/Transition Training

As conceptualized by the investigators, intermediate/transition training is the earliest phase of training in which fidelity of simulation becomes a matter of serious concern. In this phase, personnel first reporting to a ship or transferring to a ship of a different class will receive intensive training in the tasks they will be required to perform aboard the ship. This will involve the development of individual perceptual-motor skills, judgments, and communications. A complex dynamic trainer will be required for training members of the ship control party.

Objectives to be satisfied during this phase of training are as follows:

1. To develop a high level of capability relative to scanning the ship's instruments and the detection of emergency situations. Poor fidelity in simulating instrument arrangement and readouts will affect scanning habits and may prove harmful when transfer is made to the operational station, particularly since both timing and discrimination are critical on the diving stand and the ballast control panel.

2. To develop motor responses to emergencies to a high level of automaticity. By incorrectly reaching to and operating the wrong switch, the operator(s) would cause a new

hazard to the ship. This, or a delay due to perseverance of an inappropriate habit, could seriously jeopardize the safety of the ship. Physical simulation of control characteristics and arrangement is important to ensure that students experience authentic kinesthetic propioceptive and tactile cues while locating and manipulating controls. This is very important in achieving a high degree of proficiency. These cues must be developed so as to be identical when personnel transfer from the trainer to the ship.

3. To become closely attuned to the accelerations and motions of the ship as produced by both the casualty and corrective action. This is required for ship control personnel, particularly the DO and OOD. Motion and acceleration furnish significant cues to the ship control personnel both as indicators of problems and as information for judging progress of recovery action. Whether or not emergency reaction time will allow DO's and OOD's to wait for the cues furnished by ship "feel" will depend upon such factors as speed and depth. Near the surface, they might wait. Thus the meaning and use of these cues as learned in the trainer must be the same as on the ship.

4. To learn ship response to recovery actions and magnification of problems by compounding of casualties due to errors in the face of failures of various types and magnitude. This must be learned for the most part on a trainer, since drills in severe casualties cannot be experienced safely on the ship. Correct ship response is vital in learning the limits that can be taken into account in judgments. These judgments also must cover alternative actions and delays that may be desirable from the standpoint of the tactical situation, navigational factors, mission objectives, and special instructions.

(5) Advanced Training

The first objective of advanced training is to train teams. Within the scope of the present study, this applies mainly to the ship control party. What will be learned are the essential team interactions and the responsibilities among team members. It is of particular importance that individuals learn the conditions under which they will perform backup functions for another team member.

The responsibilities of the helmsman/planesman versus the DO are a case in point where discrepancies exist in the understanding of some existing teams. It is also important that team members with overlapping responsibilities learn the factors which govern performance of those responsibilities under emergency conditions. For example, under certain conditions the DO may take over emergency rudder control. Such involvement in problem details is generally frowned upon and mostitimes should be avoided.

Other objectives of advanced training are to develop high levels of proficiency in individual skills and decision-making. It is desired that teams develop the capability to deal with the most severe types of casualties and combinations of casualties.

Considerations relative to fidelity of simulation in the control training environment are the same as those for intermediate/transition training. For normal performance, the differences between classes of ships are not sufficient to prevent an individual trained on one from performing adequately on another, but they are critically different when it comes to acting in an emergency.

Stimulus situations between trainers and ships experienced by watchstanders must be sufficiently similar so that identical responses are called forth. Furthermore, where different responses are required, the stimuli presented by the trainer must be as clearly discriminable as they are aboard ship and highly similar to those experienced aboard ship.

d. Previous Personnel Training and Experience

(1) General

As part of the training requirements and training methods analysis, information was collected to obtain a basic notion of levels of knowledge and skills of present nuclear submariners. Although this was not a systematic review, curricula and guidelines for the submarine school and training commands were examined and discussed at length. In addition, interview data were obtained from officers and from a limited number of enlisted personnel about the experience and training levels of watchstanders in the ship control party.

The purpose of this skill/knowledge review was to identify the following:

1. Skills and knowledge peculiar to casualty control
2. Gaps in personnel casualty skills and knowledge due to upgrading, transfers between ships, and changes in individual shipboard assignments

3. Practices and situations tending to lead to casualties or to worsen or compound casualty effects

4. Need for extension of knowledge and sharpening or alteration of perceptual-motor skills and decision-making to make behavior that is appropriate for normal operation suitable for control and prevention of casualties

(2) Personnel Training and Experience Information Collection

(a) General

The information that was obtained on personnel training and experience does not represent a systematic sample, for two reasons: (1) a systematic survey would have been beyond scope, and (2) the experience/training levels of personnel presently assigned to ships can only be typified. It varies, very broadly, for a given ship and between ships, because of personnel transfers, upgrading (shifts to more sensitive or responsible watches), etc. In some ways, training and experience differ systematically between SSBN's and SSN's. Data were obtained from the Submarine School, the Charleston and Pearl Harbor Training Centers, and ships from both COMSUBLANT and COMSUBPAC.

(b) SSN Training and Experience

The order-of-magnitude estimates for training and experience for SSN watchstander positions considered in this study are as follows:

1. Planesmen have received 6 to 48 hr of trainer time and have served for a period of from no experience to one year of experience.

2. BCPO's typically have served many years on submarines and possibly several years on the ship to which they are currently assigned. They also perform the COW function.

3. DOOW's are commissioned officers who have 7 to 8 hr of trainer time and have generally received their first ship assignment or may have served up to, or more than, a year. During basic submarine school, officers have received about one week of submarine experience at sea.

4. ODD's, on the average, have performed in that function for approximately one and one-half years on the ship to which they are assigned.

(c) SSBN Training and Experience

Based on order-of-magnitude estimates, SSBN members of the ship

control party generally have less experience on their assigned ship than do the SSN personnel. Currently, officers and enlisted men both report they have had 6 to 48 hr of trainer time, and officers as a rule have had a week's experience aboard a submarine during their basic submarine training. Order-of-magnitude estimates for the SSBN personnel experience are as follows:

1. Planesmen can be expected to vary from no previous experience to one patrol in that position.
2. The experience of BCPO's varies from an "under instruction" status to many years. On some ships this watch is performed, on a rotating basis, by the forward auxiliaryman and IC electrician.
3. DO's (CPO's) vary in experience from "under instruction" status to several patrols.
4. OOD's vary in experience from a few months to several years.

(d) Relevant Observations for Casualty Training Methods

The more pertinent observations of existing personnel experience, training, and practices to the casualty training methods analysis are discussed below.

Turnover in personnel is high, resulting in slightly more than half of the personnel being qualified watchstanders. Newly assigned or transitioning personnel will not have the specific knowledge or skill for handling casualties aboard their assigned ship. This is an especially severe problem for off-duty SSBN crews and crews of SSN's following overhaul and extended upkeep periods. Shore training, before a patrol is begun, is thus highly desirable to reduce error-induced or compounded casualties. First, the period of time should be reduced in which qualified watchstanders are less efficient due to fatigue factors associated with heavy work loads when they are short handed. Secondly, training should provide new personnel the essential knowledge, practice, and experience for avoiding and handling casualties when they occur. The training required was identified earlier in this subsection as intermediate and advanced team training.

Periods of non-seagoing activity occur at regular cycles for SSBN crews and during upkeep and overhaul periods for SSN crews. The turnover problem, previously discussed, is particularly significant during such periods, and the implications for training are the same as those discussed in the immediately preceding paragraph. A special case arises for personnel returning from shore assignment or transitioning from diesel- to nuclear-type ships, when basic refresher training is needed in addition to intermediate and advanced

team training to combat casualties properly. It is particularly important to train all personnel in new knowledge, skills, and procedures generated from time to time as a result of recoverability studies and research.

Enlisted men trained in technical operation of the ship and highly qualified in numerous watchstander positions generally are upgraded and qualified as DOOW's and BCPO's without, or with a minimum of, shore-based training. Particularly lacking in their training background is instruction in ship principles - for example, trim analysis and control - normally received by officers who stand the DO watch.

Planesmen (that is, stern planesmen and fairwater planesman/helmsmen) typically are recent graduates of basic submarine school or personnel transitioning from other types of ships. They have a minimum of formal training and the least technical competence among their shipmates in the systems of their assigned ship. Within the current modes of operations, almost all watchstander positions require high levels of technical competence (such as sonar, communications, and weapons) to perform their primary mission. This means that the least capable persons are available to deal with the most critical casualties at ship control watches, even though the skills required during normal operation are easily learned. The implications are obvious in both intermediate and advanced team training. These are to develop individual surveillance, emergency procedures, and tracking skills to a high level of automaticity. Also, the interaction between planesmen, helmsmen, and DO's needs to be developed to a finely tuned and well practiced relationship in the face of critical situations not often experienced aboard ship.

Interviews with personnel aboard ship and observations of trainees' performance on shipboard trainers indicate a number of discrepancies crucial to the control of casualties. Estimates of depth-control accuracies and plans angles utilized, voiced in interviews with the ship's officers and crew, differed by an order of magnitude from the performance of planesmen and DO's of similar caliber observed aboard ship control trainers. Specifically, shifting to emergency control, estimated during interviews at taking two seconds or less, was observed to take more than a minute, and reaction to flooding, by several student DO's, took as much as six times as that required to initiate reaction to flooding under the worst conditions.

Knowledge disseminated about critical casualties and recovery effects assume a worst case based on high speed and deep depth. The implications of differences between operating envelopes during missions and maximum performance envelopes, such as high speed at test depth, are not usually discussed. The results seem to be a philosophy aboard many ships that, given a critical casualty, the ship will take all-out action regardless of the tactical situation, the

risk of collision, or departure from the objective of maintaining undetected submergence. There seems to be no standard procedure for reacting to casualties nor provisions in many ship bills on recovery reactions that indicate how reactions should be modified to be compatible with such factors as depth and speed in a majority of cases. The compatibility of formally voiced ship philosophy and what would be done in real circumstances is seriously questioned.

OOD's are not formally trained, nor is their role in ship-control response to casualties properly emphasized. Thus ship-control parties are now being trained without the OOD as an active member of the party. There is much resulting danger that the important OOD/DO interaction in handling the planes, rudder, BCP, and engine orders will result in confusion, failure to achieve critical reaction times, failure to include all essential recovery actions, and failure to take into account the tactical situation, mission objectives, etc.

Training of all hands in recognizing flooding as distinguished from leakage and emergency flooding is limited to a brief experience in submarine school and shipboard instructions. Only a few senior personnel have experienced actual flooding. Categories of flooding and criteria vary from ship to ship, and personnel are not provided an objective basis (anchor point) for judging the rate of flooding.

There is a tendency by ships to limit casualty control training aboard ships on the basis of frequency of experience and ease of administration. An example of the latter is to see what happens when all the lights are turned out. Other examples are communications and "dry" fire drills. An example of drill selection based on own-ship experience is to fail normal plane/steering control regularly because of the large number of hydraulic-flex-hose failures experienced aboard the ship.

Evaluation of watchstanders (planesmen) by frequently checking their observations of peripheral instruments reinforces negative training to such an extent that personnel avoid use of the combined instrumentation panel (CIP), which is arranged for optimal viewing. Instead, planesmen follow an unnatural, inefficient, and unreliable scanning pattern involving instruments beyond the normal visual field, both above and to the sides. The result is an increased error tendency in the quick detection of malfunctions. If the present practice is followed, special training in high-fidelity trainers is required. If the ship designers' intention is followed, a special classroom basic refresher session on the use of instruments and training by practice on a generalized dynamic trainer is required in the correct use of the CIP.

e. Training Cycles and Opportunities for Training

(1) General

The personnel rotation policies and training cycles differ between the attack-type SSN and the Polaris-firing, fleet ballistic missile SSBN. The training cycles of these two types of submarines differ because of the difference in missions and methods of operation.

The SSN training cycle is from one shipyard overhaul to the next, which normally occurs every 30 to 36 months. Subcycles also exist within this time span, whose duration is from the end of one deployment to the end of the next deployment. The SSBN training cycle is from the end of one patrol to the end of the next patrol. The training cycle is divided into three phases: orientation or refresher, intermediate, and advanced. Figures 2 and 3 show the time relationships between these phases of training for both SSN's and SSBN's.

Orientation/refresher training presently takes place during the latter portion of a shipyard overhaul and during the first few months after completion of an overhaul or return from an extended deployment. In addition, this phase goes on continuously, to a lesser extent, due to the transfer/position shifting of personnel. This training is conducted at shore-based schools, on prototypes, at manufacturer's plants, and on board the submarine. Training during this phase stresses individual learning or relearning of submarine-oriented general knowledge and skills, including system principles and equipment operating procedures and locations.

Personnel reporting for nuclear submarine duty for the first time must undergo an additional 8 weeks to 18 months of training prior to reporting aboard for their initial operational assignment. This training is conducted primarily at such Naval training facilities as the Basic Submarine School in New London, Conn.; Guided Missile School in Dam Neck, Va.; nuclear prototypes; Anti-Submarine Warfare School in San Diego, Calif.; Advanced Underwater Weapons School in Key West, Fla.; Fleet Ballistic Missile (FBM) Training Centers; and Fleet Submarine Training Facility (SUBTRAFAC) in Pearl Harbor, Hawaii.

Intermediate training presently takes place from the completion of orientation/refresher training through the first few weeks of a deployment. This training is conducted primarily at shore-based schools and prototypes and on board the submarine (or off-ship crew facilities for SSBN's). It stresses the learning or relearning of specific knowledge and skills required for the proper performance of duty aboard a particular sub or class of subs, including systems interrelationships and systems operating and casualty control procedures.

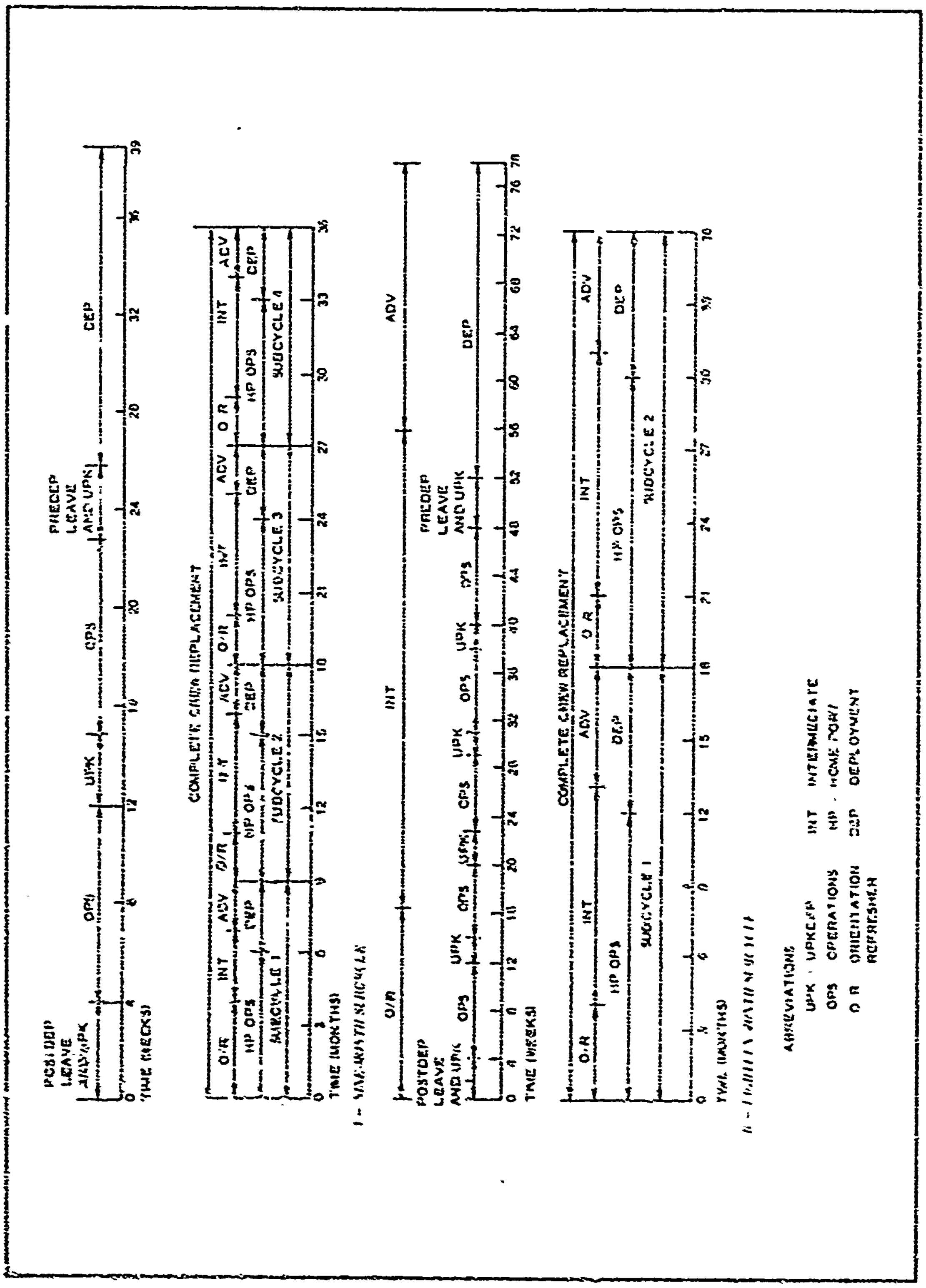

Figure 2 - SSN Training Cycles

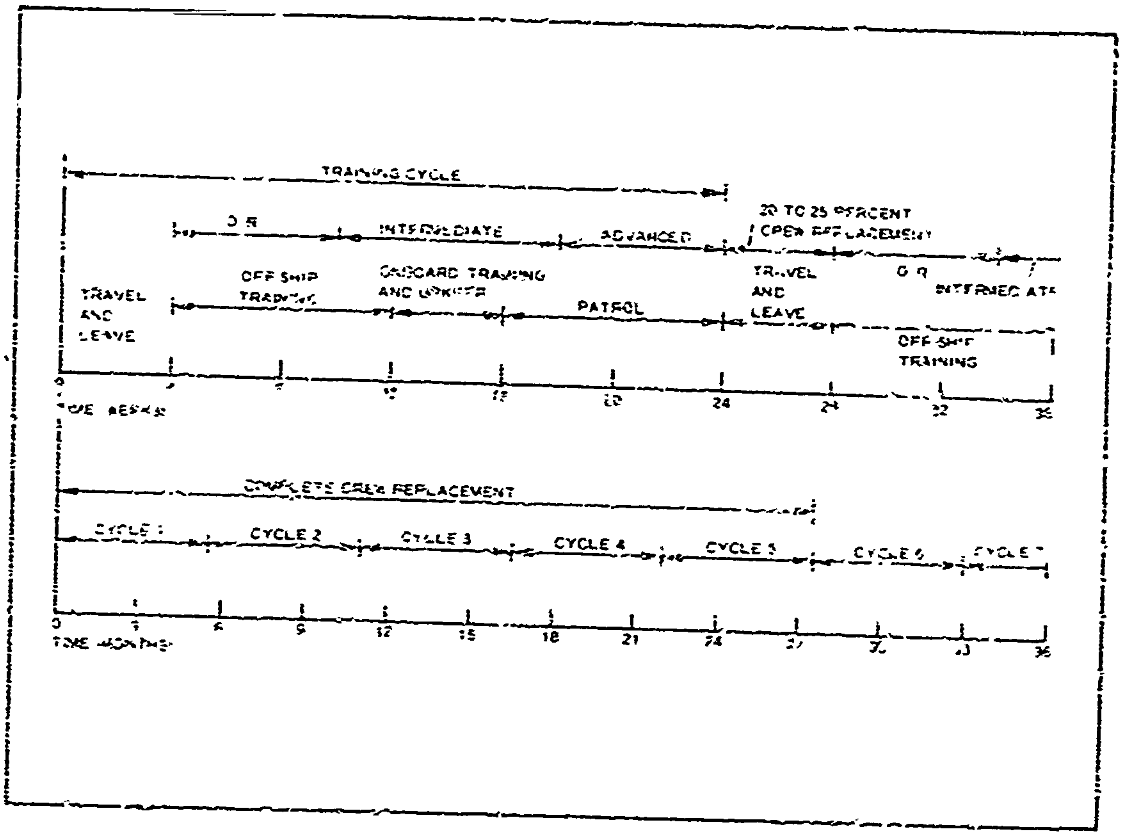

Figure 3 - SSBN Training Cycles

Advanced training by both submarine training commands takes place in the limited number of ship/casualty control trainers (primarily FBM) that presently exist, and on board the submarines. This training is presently accomplished by actual operation and maintenance of the ship's systems and equipment and through limited use of ship control trainers. Shore-based trainers (FBM) emphasize training personnel in control of those casualties that cannot be realistically and safely simulated on board the actual submarine.

(2) SSN versus SSBN Casualty Control Training Opportunities

Submarine casualty control training opportunities are limited by the availability of personnel, of submarines, and of shore-based training facilities.

The SSN has only one crew, which mans it continuously. This is advantageous because the men are continuously exposed to the ship with which they must be familiar. The personnel are always available for some form of training if the employment of the ship, in carrying out its assigned mission, will permit. However, the primary mission of an SSN often precludes conducting as much or the type of training that would be desirable. Also, during upkeep cycles

and overhauls, personnel are limited as to operation of ship systems and have no opportunity to practice ship control. Therefore, the time available to conduct casualty control training is sometimes greatly reduced.

The SSBN has two crews, "blue" and "gold," each of which mans the ship alternately for a three-month tour of duty. This is a disadvantage in that the crews tend to forget during their off-ship periods. While they are aboard ship, they are available for training, and the employment of an SSBN in carrying out its primary mission is such that it will permit more casualty control training, except for ship command and control problems and recovery actions, than that which can be conducted aboard an SSN.

Because the SSN has only one crew, it is often not practical to leave ashore personnel who may require training at shore-based training facilities. During leave and upkeep periods, personnel are usually available for individual or team training at shore-based training facilities, if these facilities are available. However, training devices, on which generalized training can be conducted for a limited number of submarine casualties, are presently provided in only 50 percent of the home ports to which SSN's are assigned. It is usually not practical, for both time and monetary considerations, to send a team of men 500 to 2500 mi to receive this training.

Because the SSBN has two crews, one entire crew is available for individual or team training at shore-based training facilities during the off-ship period. Training devices on which training can be conducted for a limited number of submarine casualties are provided in all the home ports where off-ship SSBN crews are located. In addition to the availability of casualty control training devices, off-ship crews are usually provided adequate classrooms in which to conduct training during the eight-week period scheduled for this training.

(3) *Present Training Capabilities*

Every submarine is a training device in itself. However, it is not practical to use the ship as a dynamic training device for those casualties that would impose operational hazards, damage machinery, or unduly endanger personnel. For this reason it is necessary to conduct such training in a simulated environment at shore-based facilities in the submarine's home port.

There are SSN ship control trainers with varying degrees of satisfactory casualty control simulation features at New London, Pearl Harbor, and Charleston. These trainers are the 21B20 and 21B56. The 21B20 trainer provides for high-fidelity ship control simulation of SSN's at New London. The 21B56 trainer provides for generalized training of the SSN diving control parties at New London, Pearl Harbor, and Mare Island. There are no diving or ship control trainers for SSN crews in San Diego, Norfolk, or Key West.

Fire-fighting training is provided in most home ports. However, these schools stress the methods of control for gasoline, diesel-oil, and black-oil fires. These types of fire do pose the greatest threat in surface ships. However, oil fires are almost nonexistent in nuclear submarines; the most severe fire threat is caused by the maze of electrical equipment.

There are no facilities in any nuclear submarine home port that can provide actual flooding or piping rupture casualty control training in a realistic manner. These casualties can be simulated realistically only in dynamic trainers somewhat similar to the "USS Buttercup" at the Naval Damage Control School, Philadelphia, Pa., and the "USS Neversail" at the Naval Damage Control School, Treasure Island, Calif.

2. FUNCTIONAL TRAINING UNITS

The previous lengthy discussion in Item 1, above, serves as background for the specific training methods analysis of this study. Next to be considered are the functional training units.

Determination of the functional training units consisted of grouping the knowledge and skills identified as training requirements in Section IV, Subsection Three, into closely related and integrated subject matter for instruction, demonstration, and exercise. The functional training units were designated so that students could progress from prerequisite levels, through basic and intermediate levels of individual skills and knowledge acquisitions, to advance levels of training where individuals function as team members in a manner meaningful to casualty control.

The planned approach to methods analysis was to determine functional training units at a sub-subclass casualty level considering task or part-task groupings. This approach was found to be unfeasible, since normal and emergency tasks were not always separable, and, when emergency tasks could be specifically designated, they were found to be quite elementary when considered by themselves. At the sub-subclass of casualty level, it was also found that the volume and redundancy of detail required for analysis was so extensive that a meaningful problem solution could not be reached.

Consideration of subclass casualty levels as functional training units was a better approach but also led to similar problems of data collation.

As a final decision on approach, functional training units were selected to correspond to the groups of major personnel-oriented functions required by personnel in reacting to the major classes of casualties. The major functions so identified were further limited to

roles ship personnel would have to fulfill in ship control responses. This approach resulted in a logical flow, from equipment-oriented casualties (Section IV, Subsection One), to the recovery behavior required of personnel (Subsection Two), to the knowledge and skills to be taught (Subsection Three), and to the desirable training approach, which is identified later in this subsection (Four). The result was a framework for adequately relating knowledge/skill casualty training requirements to the identification of the characteristic of devices needed for casualty control training. This provided the means for integration of the normal and emergency training requirements with the training levels and training approaches.

The functional training units are:

1. Ship command and control
2. Fire recognition/isolation/reporting
3. Flooding recognition/isolation/reporting
4. Atmospheric contamination recognition/-isolation/reporting
5. Propulsion casualties ship control effects
6. Electrical casualty recognition/isolation/-reporting
7. Ship-systems monitoring and control

3. TRAINING APPROACHES (DEFINITIONS)

a. General

The coordinated use of various types of training devices is required to impart the knowledge and develop the skills of the casualty control student. The most effective training device available to an instructor is frequently the actual object under discussion or, in the case of casualty control, it would be the creation of the actual situation if the latter were feasible, safe, and conducive to learning. For obvious reasons, effective use of training aids and/or devices must be substituted to accomplish the same objectives in the case of casualty control training.

b. Classroom Training Aids

(1) General

Training aids were selected on the basis of (1) the functional training unit and level of training level, (2) the effectiveness of the training aids to accomplish the intended objective, and (3) the interrelationship of the training aids to each other and other training devices. The final selection of training devices also included consideration of their appeal to more than one sense, their ability to attract and hold

attention, their ability to focus the students' attention at the proper time, and their cost.

Training aids can be generally classified as graphic, programmed, auditory, projected, three-dimensional, and films and closed-circuit television. The advantages of each type are presented below for purposes of review.

(2) Graphic Training Aids

Graphic training aids include chalkboards, posters, wall charts, flash cards, flannel boards, graphs, pictures, diagrams, and study cards that are either placed in the classroom for observation or given to the student as a handout for drilling or for his future reference. All these aids make their point through the sense of sight only and are less effective than those appealing to more than one sense. The advantages of the more frequently used graphic training aids are discussed below.

Still pictures in the form of wall charts and posters are advantageous when material that does not involve motion is being presented. A major advantage is that the information is presented for prolonged observation by the student and that the instructor can repeatedly refer to it during the classroom instruction period with minimum distraction to the student. Information in this form is usually general in nature, such as shop warnings, general arrangement and location drawings, etc.

Flash cards and flannel boards are used to bring home an idea or main points of the classroom instruction. They are also used effectively in drill or review.

Sets of study cards have the major advantage of training the student to approach a given problem analytically by studying the problem, selecting and erasing hidden answers on the study card, and identifying the order of his selection for subsequent evaluation. This is an effective training device that could be carried on shipboard or used ashore for periodic refresher training.

Graphs, pictures, and diagrams can be in the form of wall charts, posters, or student handouts. When given to the student for permanent retention, periodic review sessions can be conducted on shipboard to refresh the students' knowledge in these areas.

(3) Programmed Training Aids

Programmed instruction, which includes programmed books and teaching machines, is a relatively new method for supporting learning so that students learn rapidly and thoroughly. The general advantages of this type of aid include (1) allowing the student to progress at his own rate, (2) uniform level of training in the subject

matter, (3) savings in training time, (4) individual training, (5) decentralization of training, and (6) relieving instructors of teaching routine material.

Some specific advantages are as follows. Programmed textbooks can be utilized whenever and wherever the student is located. They can be used not only to learn the original subject matter but also to conduct periodic refresher training.

Teaching machines have been found effective in increasing student motivation, enhancing the efficiency of communication with the student, and improving instructor control of training materials. Special-purpose teaching machines are also effective in teaching such particular abilities as mechanical-manipulative skills.

(4) Auditory Training Aids

Limited use of auditory training aids is made to train the student in the recognition and classification of audible signals. This category includes wax, wire, or tape recordings and is advantageous when the recognition of sonar signals, warning buzzers, or impending equipment failures is the subject matter to be learned through the sense of sound.

(5) Projected Training Aids

Slides, animated schematics, transparencies, and opaque-projection material are grouped in one category because the basic type of information projected falls in the same category and each can be arranged or rearranged in different sequences to provide the training needed by different groups. Slides are particularly advantageous because they are compact and portable. The image size of slides can also be varied according to the size of the group.

Transparencies are the most often used training aid because of their versatility and ease of preparation.

Opaque-projection material has the same instructional advantages as slides and transparencies, with the exception that a certain amount of quality of the projected image is sacrificed. The big advantages of opaque materials are the savings in time and expense required for reproduction to a slide or transparency of the subject matter. Illustrations from books and manuals can be directly projected.

An important variation of this group of training devices is the animated schematics by means of which an instructor can actively manipulate a part to teach system relationships, signal flow, etc.

Film strips have a definite advantage when still pictures are to be shown in a fixed sequence. Some applications of this technique

include step-by-step procedures and other "canned" presentations that lend themselves to a fixed order of instruction.

(6) Three-Dimensional Training Aids

Three-dimensional training aids include models and mockups. The major advantage of models, in addition to their being three-dimensional, is their ability to be scaled down or up as required for good instruction. Some models are also designed to permit disassembly for studying the item in more detail. Mockups are useful in demonstrating basic principles or ideas only before proceeding into more complicated phases of instruction.

(7) Films and Closed-Circuit Television

The most important advantage of motion pictures is their ability to portray motion, relationships, and system effects, either actual or simulated, through animation. Fast processes can be slowed down and slow processes accelerated to aid in the student's understanding of the subject matter. Sound and visual effects can be coordinated. A major disadvantage in the use of motion pictures is the difficulty and expense incurred in making changes to the film after initial release.

Closed-circuit television has been used very effectively in schools to present a unit of instruction to a large number of students simultaneously. Closed-circuit television is also effective within the classroom where the camera picks up a detailed process being performed by the instructor, such as disassembling the firing mechanism of a gun, while all students watch the procedure from their desk through television receivers placed strategically in the classroom. Television also can be used to present effects that students could not observe at the "eye" of the camera for safety reasons.

c. Demonstration Trainers

As defined for use in the training methods analysis, principal consideration has been given to devices that can provide students with audio-visual effects. Special facilities will probably be required. Such devices are particularly applicable when actual exposure to the effects to be demonstrated and experienced during the corrective action involve a high level of risk as to safety. Also, such demonstrations are applicable when the capability for providing essential perceptual experience to trainees is not feasible because of the low frequency of natural occurrence. Demonstrators are especially desirable when the dynamic characteristics of an observed emergency situation are necessary for the adaptation and judgment of trainees in their duty assignments.

d. Procedural Trainers

The most notable characteristic of procedural trainers is that they

are "open-loop," full-scale representations of a system or part thereof. As the name implies, their purpose is to provide students practice in the performance of procedures, that is, discrete operator movements in a prearranged sequence or specific actions to a simulated indication. The term "open loop" refers to the fact that system (equipment) simulation is not required to provide feedback to the trainee as a basis for his continuing action.

e. Generalized Dynamic Trainer

A generalized dynamic trainer is a device with built-in feedback elements that reflect student action. A diving trainer of this type is not intended to be a highly faithful representation of a given ship environment performance of the ship to which the trainee will be eventually assigned. The sense in which "generalized" is used when applied to ship control trainers involves fidelity of hardware arrangement, system operation, and hydrodynamic characteristics of ships. In each of the latter simulation categories, the intent would be to duplicate what is common between classes of ships and to omit or select typical characteristics of uncommon features.

f. High-Fidelity Dynamic Trainer

A high-fidelity dynamic trainer is a closed-loop hardware device similar to the generalized dynamic trainer. A high-fidelity trainer is considered to be a hardware representation of a specific operating system or part thereof that simulates operationally the "real" situation or piece of equipment. The simulation is realistic with respect to both equipment performance and appearance.

The major application of such a device is for advance individual and team casualty training in which a training device is so designed that a high degree of behavioral fidelity is achieved and the skills/-knowledge learned are positively and directly applicable to job performance. This type of device can be exemplified by existing sophisticated ship control trainers that act like diving stands of specific ships.

4. SHIP COMMAND AND CONTROL CASUALTY TRAINING APPROACHES

a. General

In preceding parts of this section, training methods, levels of training, personnel to be trained, types of training devices, and functional training units have been defined. On this basis an analysis, summarized in Appendix G, Table G-I, has been performed. The main results of this analysis are presented in Items b through l, below, which follow the outline of knowledge and skills required for training as presented in Table I. The casualty training requirements

(critical skills and knowledge) are listed along with recommended training methods.

b. Requirement No. 1

The first training requirement is: to ensure a high degree of tracking capability by planesman so that cues of a malfunction for indicators, control system, or ship feel are not confounded with erratic or improper planes or depth control. For enlisted men at the basic level of training, there is a requirement for a generalized ship control trainer. This trainer should include the physical representation (control display arrangement, etc.) of the diving stand. Displays required include the CIP, auxiliary indicators, shallow depth gage, and digital speed indicator. Controls required include the AMC/control mode selector panel, control columns, and manual-pilot hydraulic power transfer valves.

Malfunctions to be simulated include:

1. Flooding forward, amidship, and aft at rates progressing from 1/2 to 16 in. at maximum increments equal to multiples of two
2. Stern plane failures at full rise or dive, at the position being maintained by the trainee or at an intermediate angle of 0 to 25 deg selectable at the discretion of the instructor
3. Fair-water plane failures such as those specified in No. 2, above
4. Rudder failures hard right and left or at intermediate values at the position being maintained by the trainee or at an intermediate angle to be set at the discretion of the instructor
5. AMC failure
6. Diving panel indicator failures
7. Normal hydraulic control failure
8. Audible alarms
9. Electrical-powered communication circuits

The trainer should provide the means, such as closed-circuit-television instant replay, by which the student can be furnished an appraisal of the depth and ship angle maintained and of the plane angle utilized.

Ship response to planes/steering casualties should represent an existing nuclear SSBN or SSN ship with a difference from some representative ship no greater than differences between SSBN and SSN types of ships.

At the intermediate level of training for enlisted men, a high-fidelity, dynamic ship-control trainer as described in Appendix F is required. Functions and malfunctions to be simulated are listed in the preceding paragraph. Fidelity must be such that vernier tracking behavior by the trainee is adequately supported by control-display rates and platform motion that faithfully represents plane control actions aboard the ship. The means for providing an immediate replay of student performance and accuracy is recommended as in the basic trainer above.

c. Requirement No. 2

The second functional training unit is: to develop in planesmen and DO's proper scanning habits and the ability to shift attention among available indicators, thus avoiding mesmerization by one indicator or tunnel vision. For the basic level of training of both enlisted men and officers, classroom aids and a generalized dynamic trainer are required. Classroom aids in the form of charts or slides and supported by lectures/discussions should emphasize the meaning, intent, accuracy, and reliability of CIP indicators. They should also clarify the intended use of peripheral diving-station indicators as monitoring devices for the DO and OOD and as backup for CIP indications.

A generalized dynamic ship control trainer of the type described in Item b, above, should also be used for basic training in this training requirement. However, as an additional feature, the BCPO trainer functions described later in Item 10 of this subsection should be integrated on the diving platform for purposes of basic submarine officer training.

Beyond the basic/refresher level of training, diving control parties require a physical representation of the diving panel and BCP display arrangements almost identical to those of the class of ship to which they are assigned. Since estimated time allowed to identify an abnormal indication as part of the total time to react to a casualty varies from a fraction of a second to a few seconds, search time must be minimized. It follows that reactions in bringing the eye to bear on the abnormal indication(s) must be highly automated and not subjected to interference by stress. For officer training, especially individual skill in scanning, the environment of the total ship control party is required so that their surveillance of indicators and ship motion can be practiced on a time-shared basis with crew supervision and monitoring activities.

The capability to provide an appraisal of personnel attending habits and "set" should be made available to the operator/instructor. A method of providing this capability would be for the instructor to insert indication failures singly or in combination with features for timing the interval between failure input and initial trainee reaction.

d. Requirement No. 3

The third training requirement is: to develop in planesmen and DO's a capability to switch mental sets rapidly from that appropriate for normal, AMC, or one-man control to that appropriate for emergency action. This includes prompt and discriminating reaction to alarms, abnormal indications, or abnormal ship motion. This training requirement is applicable to both enlisted and officer personnel in basic/refresher and intermediate/transition levels of training.

Basic/refresher training involves the use of classroom aids such as slides, charts, and film strips, with a supplementary film to depict the simulated emergency environment for the purpose of establishing personnel adaptation and inducing the proper feeling of urgency. In addition, the aids will relate BCP to diving panel indications and alarms. They also will relate indications/alarms to controls and proper control actions.

The use of a generalized ship-control trainer will also teach students the rudimentary skills in shifting from a "normal" to a stress situation. Furthermore, trainees will learn by practice to associate the shift in "set" and readiness-for-emergency action with cues furnished by both ship-control-platform movements and panel indications.

A high-fidelity ship-control trainer is needed to develop discriminatory responses to specific cues of normal/abnormal performance of the specific class of ship to which the enlisted and officer personnel are assigned. Depth, speed, and cross-coupling effects on ship accelerations in the X-Z plane (as represented by indicators and trainer platform motion) should be almost identical to the effects of plane and flooding casualties, and casualty recovery actions (such as emergency MBT blow effects) on the class of ship to which personnel are assigned.

The means for furnishing students an appraisal of the adequacy of their performance is needed. The capability specified in the last paragraph of Requirement No. 2 (Item c, above) would be appropriate.

e. Requirement No. 4

The fourth training requirement is: to develop in planesmen and in the BCPO the perceptual motor capability to shift to alternate modes of operation, such as rate control, manual overrides for emergency blow or plane control, and local (emergency) manual control of the planes, rudder, and vents. This requirement applies primarily to motor responses of enlisted men in intermediate and advanced team levels of training. Basic normal operating capabilities and knowledge of system characteristics is assumed. The purpose is to develop the indicated emergency procedures as highly automatic

reactions to dynamic cues presented by ship movement, alarms, and BCP/diving panel indications. To achieve this purpose, a high-fidelity dynamic trainer is required. The latter should simulate the class of ship to which personnel are assigned with respect to arrangement of controls, control-display rates, and control-ship response rates and effects.

An additional important training capability under this requirement includes features by means of which the operator/instructor can demonstrate the effects on recoverability of student inefficiencies, response delays, omission of emergency procedural steps, or erroneous responses. Typical examples from the past, in which minor to moderate casualties or malfunctions have been escalated by personnel error(s) into critical casualties, including loss of life and ships, should be demonstrable.

f. Requirement No. 5

The fifth training requirement is: to ensure in DO's the ability to analyze and maintain trim control so that cues of a malfunction from indicators, control system, or ship feel are not compounded with a heavy condition, down angle, up angle, or list due to an improper or unknown trim. Basic casualty control training in trim analysis and control is required for junior officers in Submarine School, officers being assigned to sea duty after shore assignments (refresher), and senior petty officers being upgraded to serve as DOOW's. A means for upgrading and refresher training at operational submarine bases is considered to be the primary consideration, since the basic submarine school curriculum contains an adequate course of instruction in this area.

The required basic refresher and upgrading training approaches include classroom aids, stick diagrams, charts, films, transparencies, and texts covering the equilibrium polygon, variable ballast tanks, trim system, etc. Scale models of the system would also be useful. Although classroom aids are the primary means for instruction, a generalized dynamic ship-control trainer is also needed. Such a device should demonstrate the effects on buoyancy of speed, depth, and plane angles, as well as the effects of trim on casualty recoverability. In particular, effects should be demonstrated near the surface and at deep depths.

Trim analysis/control and associated casualty control training require a high-fidelity dynamic ship-control trainer both to ensure high individual skill levels of enlisted and commissioned DOOW's and to develop team interactions between the DOOW, BCPO, and planesmen. Effects to be incorporated include those enumerated for the preceding ship command and control training requirements, plus anomalies in which compounded casualties and errors or unusual failures can be confused with an out-of-trim condition. Teamwork by the ship-control party and sophisticated judgment based on

knowledge of the effects of ship system status and actions are required to deal with the type of anomaly considered.

To provide DO's and ship-control teams with an objective appraisal of their handling of complex problems and errors, the previously mentioned closed-circuit television with instant replay is suggested.

g. Requirement No. 6

The sixth training requirement is: to provide in planesmen the ability to recognize, diagnose, and initiate appropriate corrective responses for stern planes, fairwater planes, and rudder casualties. The required training environment will be fulfilled by the training approaches described in Items b through e, above.

h. Requirement No. 7

The seventh training requirement is: to develop in DO's the ability to recognize, diagnose, and direct corrective action for depth and depth-rate control problems due to indications of stern plane, fairwater planes, or rudder casualties. The required training environment is the same as that specified in Items c, d, and f, above.

i. Requirement No. 8

The eighth training requirement is: to develop in DO's the ability to initiate ship-control actions in response to general emergencies and alarms, and as directed by the OOD. This will include emergency surfacing, depth change for emergency ventilation, and depth change to ordered depth. Training is required at basic levels for officers and PO's being upgraded to stand the DO watch. After assignment to a ship, during off-duty cycles, and during upkeep or overhauls, intermediate and advanced training is needed to sharpen judgment, communication, and supervision of the planesmen and BCPO.

Significant basic and intermediate training of personnel in the evolutions identified in this training requirement can be accomplished with classroom aids and films. The latter should show system animation, correlated in real time and by flashbacks with correct procedures. Procedures to be taught include format and timing of commands and acknowledgements. Classroom aids and films should also depict potential hazards and casualties that have been experienced during these evolutions in the past.

Practice to develop rudimentary skills in the DOOW procedures to carry out the indicated evolutions can be accomplished on the generalized dynamic trainer described above in Items b and c and with additional malfunction capabilities. These capabilities are in the area of emergency MBT blow, vent controls, and air-bank pressure failures.

Practice to develop high levels of individual and team skills in the aforementioned evolutions will require the use of a high-fidelity, dynamic ship-control trainer. The device for this purpose should include surface effects and representation of tactical and navigational factors to be simulated verbally by the operator/instructor. Special effects should include the possibilities of broaching, excessive ship angles, loss of propulsion, and ship response to blowing and venting of special tanks.

j. Requirements No. 9 through 12

The next four training requirements are treated in combination. They are as follows:

1. To develop in OOD's/conning officers the ability to scan and monitor ship-control indications and BCP indications, to evaluate ship performance so as to detect abnormal ship status, and to monitor the BCPO and the DO for performance that is inconsistent with ship safety and the tactical situation

2. To develop in DO's and OOD's an appreciation of the safe operating envelope for the ship, combining such factors as depth, trim angle, speed, buoyancy, powerplant lineup, depth rate, and the tactical situation

3. To develop in DO's and OOD's an understanding of various corrective actions and combinations thereof to include the effect of alternate actions on recovery, and the limitations and implications of the use of these recovery actions

4. To develop in OOD's the skill to initiate expeditiously the proper casualty control procedures

The approaches for the above requirements include classroom aids, films, and a generalized ship-control trainer for training basic officers and enlisted diving officers. Classroom aids and films are needed to depict subject matter such as the following:

1. Nature of flooding - rates, locations, and effects

2. Components, locations, and system characteristics of the SUBSAF package

3. Modes of control surface failure

4. Recoverability curves and nomograms for flooding and planes failures

5. Communications systems, including sound-powered, MC systems, and alarms.

No additions need to be made to the dynamic ship control trainer approaches previously generated.

k. Requirement No. 13

The thirteenth training requirement is: to develop in the stern planesmen, helmsman, BCPO, DO, and OOD skill in evaluating the progressive effects of recovery action and performance of followup action necessary to restore a safe operating envelope. This is interpreted as an advanced team training requirement and demands high-fidelity simulated ship performance and ship systems response. The objective will be to provide accurate feedback to ship-control parties on the results of their decisions, reaction time, and sequencing of recovery actions.

The high-fidelity simulator-trainer should thus be equipped to reveal depth excursion; air-bank management, including negative recoverability effects, such as exceeding crush depth; loss of propulsion due to excessive ship angle; or loss of capability to maintain the ship on the surface due to air-bank pressure exhaustion mismanagement. This trainer also should enable the control party to practice correct followup actions to avoid broaching and unnecessary departure from the patrol objectives.

The capability to provide the crew with an objective appraisal of their actions to recover from compounded and complex casualties is mandatory for this training requirement.

l. Requirement No. 14

The fourteenth training requirement is: to exercise the ship-control team in effective interactions and communications. With the exception of a communications procedures trainer, no additional training devices are identified for this training requirement. The principal needs are a multiple-booth communication procedures trainer and a high-fidelity ship-control trainer, both of which are discussed elsewhere.

Two special features that should be provided are (1) practice for the stern planesmen and fairwater planesman/helmsman under DO direction in coordinating their control of depth and trim angle and (2) practice for the DO and OOD in coordinating their orders to the BCPO and helmsman.

5. FIRE RECOGNITION/ISOLATION/REPORTING

The training requirements for fire recognition, isolation, and reporting are listed in Table I. The methods analysis chart, Appendix G, Table G-II, indicates that there were no areas in which officer training and enlisted-man training were different with respect to the training aid requirements.

The training requirements for fire recognition, isolation, and reporting with accompanying recommendations of training methods are given below.

The first training requirement is: to ensure that all personnel have knowledge of the nearest communications/alarms from any location in all levels of each compartment. This requirement is a ship-peculiar, individual skill and is best taught during ship qualification. Implied in this requirement is the individual's ability to utilize effectively the communication and alarm systems under normal conditions and while wearing breathing masks.

The second training requirement is: to develop in all personnel a knowledge of all combustibles or electrical sources of fire in any part of their assigned watch station. This requirement is also in part ship-peculiar; however, the knowledge of shipboard combustibles can be and should be presented in basic training in the classroom environment. The instruction could be reiterated at the intermediate level of training, with emphasis on the flammable characteristics of new materials and the properties of extinguisher agents.

As in the first requirement, the most effective training would be during ship qualification. A training film would serve as an effective supplement to demonstrate the flammable nature of shipboard materials. This film could be closely integrated with other classroom training requirements. It would be of special value to show the relative effectiveness of water, CO_2, Ansul, or other materials in combating such fires as plastics, electrical, Mylar, etc.

The third training requirement is: to develop in all personnel the knowledge of equipment arrangement, controls, and location for isolation of electrical equipment or combustible materials involved in a fire. The general location of these items can be taught in part in basic training; but, because the specific locations and equipment arrangements vary from class to class and even from ship to ship within a class, instruction is best given on the intermediate level of training. Again, the most effective training would be on board ship. This training could be presented to teach individual skills as well as simulate fire drills requiring team action. This type of training is presently being utilized in the fleet.

The fourth training requirement is: to develop in all personnel the knowledge of the location of fire extinguishers, protective gear, and breathing masks in all compartments. This requirement is closely related to the preceding requirement, so training can be conducted in the same manner.

The fifth training requirement is: to develop in all personnel the ability to judge the severity of a fire. This requirement may very well be satisfied in current fire fighting schools. A facility is required where individual recognition and fire-fighting proficiency is

achieved by presenting realistic submarine fire-fighting problem situations, including the actual combustible materials and realistic techniques. This type of exposure is the most effective method of developing a man's ability to judge the severity of a fire. A film could be used to supplement this training.

Additional study is needed to determine the most desirable characteristics for updating fire-fighting trainers.

6. FLOODING RECOGNITION/ISOLATION/REPORTING

The training requirements for flooding recognition are presented in Table I. The methods analysis chart, Appendix G, Table G-III, shows only a few instances in which officer training and enlisted training are different with respect to training aids. These differences will be pointed out in the subsequent discussion.

Flooding training methods analysis discussions will consider the approaches to fulfillment of individual training requirements as they are satisfied throughout the training levels. The casualty training requirements (critical skills and knowledges) are discussed along with recommended training methods.

The first training requirement is: to develop in all personnel the ability to recognize the various manifestations of high-pressure flooding, impingement, and vaporization. It is important to emphasize the aspect of "high pressure" in this requirement. The ability to "recognize" can be developed only by visual presentations, because the high-pressure aspect rules out actual participation in this type of flooding training. The training approach, therefore, is to provide an "outside-in" demonstration facility to show these high-pressure effects.

This facility would also provide realistic sounds associated with high-pressure flooding and could possibly be integrated with lower-pressure "get-wet" type of training. These high-pressure effects might be presented just as effectively in a training film. Classroom aids, such as photo slides, could also be utilized but with limited effectiveness.

The flooding film and aids are urgently needed and could be utilized on all levels of training. One major contribution of these devices to ship casualty control training would be the presentation of high-pressure effects on a scaled basis at different rates so that a trainee would then have some basis for estimating the severity of a shipboard flooding situation. At present, there is no satisfactory method to provide this training.

At least one high-pressure, outside-in flooding demonstration trainer

is needed for several reasons. The first is to show the effects of flooding at depth through hole sizes typical of SSBN's and SSN's, such as one-quarter, one-half, one, two, and four inches. Some of the effects to be seen would be flooding rate in the compartment, damaging of equipment, and vaporization. Another reason why such a device is required is that, once built, it could also be used as a valuable research tool for developing new concepts of flooding damage control at depth as well as dynamic stress testing of any new configuration of piping and valves that might be developed in the future.

A second training requirement is: to develop in all personnel the knowledge of functional flow, hull openings, and other sources of flooding by physical location within compartments. This requirement indicates a need for general knowledge of sources of flooding as well as a specified knowledge of the physical location of potential flooding sources within compartments. On the basic level, this requirement can be partially covered by classroom lectures and aids. The basic-level shipboard visit can serve as a first exposure to these flooding sources, and the latter should definitely be emphasized on these visits.

This requirement cannot be completely or well satisfied until the trainee is assigned to a specific ship. This is at the intermediate training level, where he may be given instruction to develop specific ship knowledge and visual memory of structure and piping necessary to locate flooding sources. For a transitional student, the training would emphasize the new and different features of the ship to which he is transferred.

The most effective training for this requirement would be the actual ship, although complex scale-model cutaways might be considered for advanced training.

A third training requirement is: to develop in all personnel the knowledge and visual memory necessary to isolate or retard all possible sources of flooding. This applies to the hull and backup stops as well as to the SUBSAF control panels in adjacent compartments or levels within a compartment. This requirement can be satisfied by using the same approaches as those in the second requirement, above, with the addition of a generalized dynamic "get-wet" training device.

The purposes of the get-wet trainer are twofold. One is to ensure that personnel do not under- or over-react to a flooding casualty. The need exists for a get-wet trainer that provides realistic sights and sounds to adapt the trainee to the flooding situation, since only two or three senior officers from the dozen or more ships interviewed had experienced flooding. Based on the anecdotal evidence, their first-time reaction to the sight of water entering the ship was not adaptive.

The other purpose of get-wet training is to provide an objective anchor point for scaling the rate of water influx. To fulfill this requirement completely, the get-wet trainer would be utilized at all levels of training. A basic trainee would get his first flooding exposure under stress while learning damage control techniques. The trainer would also be useful at the intermediate level for training the man transferring from diesel to nuclear in more realistic get-wet situations.

At the advanced level, teams can participate in flooding, isolation, and retardation problems. This type of general-emergency problem situation requires that personnel, at the scene, improvise an organization to handle the casualty control functions until the damage control party arrives or to control the damage themselves. Data collection and personnel interviews indicate that additional study, related to the get-wet trainer, is needed to determine the characteristics of such a device.

A fourth training requirement is: to develop in all personnel the knowledge of what systems would be affected directly by flooding and quick fixes or improvisations to protect essential systems from flooding damage. This requirement is also, in part, handled by classroom training aids and probably will be well satisfied by a generalized-flooding, get-wet dynamic trainer. The utilization of the training device to seek quick fixes and improvisations lends itself well to forceful presentation.

It is felt that there exists an immediate need for classroom training material to solve this requirement at the intermediate level. This will require some additional study to determine how flooding in various locations on the ship can affect the numerous ship systems. The requirements for team training are as indicated in the third requirement, above.

A fifth training requirement is: to develop in all personnel a knowledge of system effects due to various flooding isolation actions and of optimum lineups to optimize residual ship control capability. Much of the information to satisfy this requirement can be presented effectively in a classroom situation. Additional knowledge of the effects of flooding and isolation action can be derived from the generalized ship-control trainer at the basic level. This knowledge can be improved upon in the intermediate and advanced levels through the use of a high-fidelity, dynamic ship-control trainer. A generalized trainer could also be used at these levels with reduced effectiveness due to hydrodynamic ship response differences. In upgrading enlisted men, the BCP operation of the generalized dynamic ship-control trainer would be valuable in teaching lineups and the effects of flooding casualties on ship control.

This training would include the knowledge and skills associated with the hydraulic-system functioning and mode controls, trim and drain

systems, snorkel and mast operations, main-ballast-tank blow and vent operations, negative or hovering systems, and hull-opening indicator systems.

A sixth training requirement is: to develop in all personnel the perceptual motor skill to isolate correctly the affected systems, such as electrical units or circuits, and achieve the optimum line-up for continued ship recovery capability. This particular requirement is best realized by shipboard training for both officers and enlisted men, with the possible exception of the maneuvering-room watchstanders, whose panel operating functions have been excluded from the scope of this study. It is, however, necessary that officer training begin in the classroom, with a consideration of optimum lineups on the diving panel, of the BCP, and of requests to the maneuvering room, as well as alternate modes of ship systems operation during and after potential flooding casualties. Perceptual-motor skills in the isolation of electrical units, under impending flooding casualties, can be partially accomplished in basic training by early exposure to isolation techniques on board ship, although a get-wet flooding trainer will probably prove necessary upon further study.

The final training requirement for flooding casualty control is: to develop, in qualified watchstanders, the capability to communicate properly the initial report of flooding as to its nature and location, plus amplifying status reports under conditions of stress, noise, and physical interference. This requirement indicates a definite need for communications training. The best approach is a procedures trainer for utilization in the development of individual and team communication skills. This implies that training be given periodically throughout all training levels to both officers and enlisted men.

Communications training is also of special importance for upgrading enlisted men to act as DO or BCPO. As a supplementary aid for flooding training, the generalized, dynamic get-wet trainer should probably have communication circuits for use during stress, noise, and flooding. Functional requirements for the communications trainer are included in Section V of this report.

7. ATMOSPHERIC CONTAMINATION/RECOGNITION/CONTROL

The training requirements for atmospheric contamination have been developed in Section IV, Subsection Three. The methods analysis chart, Appendix G, Table G-IV, shows that the required devices and training are essentially the same for both officers and enlisted men. The following discussion of training approaches for atmospheric contamination outlines the means by which the training requirements can be fulfilled.

The first training requirement is: to develop in all personnel the ability to recognize the following gases:

Aerolein	Monoethanolamine
Amine	Ozone
Ammonia	Phosgene
Chlorine	Selenium
Formaldehyde	Sulfur dioxide
Hydrogen chloride	Hydrogen fluoride

This requirement, as well as the second requirement, below, involves the development of individual skills in keeping with the definition of training levels in this study. No advanced team training is anticipated. The recognition of these gases requires knowledge of their potential sources, odors, effects on personnel, and administration of antidotes. Demonstration and/or description of the gases and their odors could be provided readily at both the basic and intermediate levels. Classroom aids may consist of slides or charts and small quantities of material with characteristic odors that can be safely and economically released from vials.

The second training requirement is: to ensure that personnel know the location of the nearest communication box in the various watch areas. This requirement is a ship-peculiar individual skill and is best taught during ship qualification.

The third training requirement is: to teach the location of materials and/or controls required for emergency revitalization. This requirement is envisioned as being best taught on board ship. However, classroom instruction utilizing actual emergency equipment, its usage, limitations, etc. could be provided. This requirement also includes a need to provide communications training while utilizing emergency measures, such as the emergency breathing apparatus.

On the upgrading of enlisted men, there exists a definite need for training to ensure that potential BCPO's are thoroughly familiar with the location of all materials and/or controls required for emergency air revitalization. This is necessary since, in the emergency situation, the BCPO is the main communicator and must have this knowledge to be effective.

This discussion leads to the fourth training requirement for atmospheric contamination control, which is: to develop the requisite skills and knowledge, including BCP operation and local actions, for emergency ventilation. This requirement is best developed on the intermediate level with ship-particular-type training. Training on board ship and in the classroom are equally important in teaching ventilation-system operational characteristics. Again,

when enlisted men are upgraded to serve as DOOW's, it is recommended that they receive special training on either BCP emergency procedures trainers or generalized, dynamic ship-control trainers.

Personnel being upgraded for BCP operation need to be trained with the use of classroom aids and receive practice on a procedural trainer with symbolic representation of flow. The trainer should have a realistic control display arrangement. As in all training of this nature, the first exposure to ventilation evolutions can and is presented to officers and enlisted men on the basic level.

A training film would appear to be useful in partially fulfilling the four preceding requirements and should perhaps be developed as a supplement to the other training apparatus as outlined above.

8. PROPULSION CASUALTIES (SHIP CONTROL EFFECTS)

The training requirements for propulsion casualty effects have been developed in Table I. The first skills/knowledge training requirement is: to teach command and control officers who are not nuclear trained to evaluate the residual capability of the propulsion system upon report of system casualties and status. By definition, this requirement is satisfied on the intermediate level by classroom training dealing with the propulsion system. Practice on a generalized dynamic ship control trainer would be of value to show effects of propulsion on alternate recovery actions. A film dealing with this subject could be considered as a supplementary aid.

The second training requirement is: to exercise control officers to solve ship-control problems in combination with propulsion-system casualties. The best training approach for this requirement is a high-fidelity dynamic ship-control trainer. High fidelity is necessary to present the problem situation correctly and to provide objective knowledge of results as essential feedback for learning.

9. ELECTRICAL RECOGNITION/ISOLATION/REPORTING

The training requirements for electrical recognition/isolation/-reporting have been developed in Table I. As indicated by the methods analysis chart, Appendix G, Table G-VI, training methods for officers and enlisted men are essentially the same. The training requirements (skills and knowledge) for electrical casualties recognition, isolation, and reporting are described below with accompanying recommended training methods.

The first training requirement is: to provide knowledge of fundamental electrical malfunction indications. This requirement could be well handled through classroom training supplemented by demonstrations of typical electrical equipment operation. Included in this presentation would be indications of normal and abnormal operation.

A second training requirement is: to learn the location of electrical isolation boxes. The actual location can be taught only by thorough shipboard training. The complexity of wiring and interconnection capability requires that a man be as knowledgeable as possible in ships and standard coding techniques, so that not only will he have no difficulty in locating the box, but no difficulty in correct isolation.

This leads to the third electrical training requirement, which is: to provide an understanding of equipment functions in the overall electrical system. This understanding is necessary if a man is to perform successful emergency isolation. Presently, a man may not isolate major equipment unless directly ordered to do so.

The ability of the individual to judge the severity of the malfunction should be developed as quickly as possible by classroom instruction and training film. The intent should be, not to authorize the man to isolate major equipment on his own judgment, but to provide him with the ability to gain access to the situation in an intelligent manner, enabling him to be alert to probable orders.

The fourth requirement is: to ensure correct communications with necessary personnel. Requirements very similar to this have been previously discussed for flooding, fire, and atmospheric contamination and therefore will not be repeated here.

10. SHIP-SYSTEMS MONITORING AND CONTROL

a. General

The training requirements for ship-systems monitoring and control are listed in Table I. The methods analysis chart, Appendix G, Table G-VII, indicates that there are different requirements and training approaches for officers and enlisted men. The ship-system monitoring and control discussion in Section V outlines the approaches for fulfilling these requirements.

Items b through h, below, cover training requirements for the BCPO, DO, OOD, and local watchstanders.

b. Requirement No. 1

The first training requirement is: to detect malfunctions based on

local indication(s) at the BCP. This training requirement for officers was considered to be satisfied best by participation of the DO and OOD in advanced team-training problems. To provide data sufficiently accurate for the DO or OOD to make meaningful decisions, the team trainer must be of the high-fidelity, dynamic ship-control type. The BCP's normal operation and normal systems function, as well as malfunction cues and troubleshooting procedure, can be taught in the classroom at both the basic and intermediate levels of training. To satisfy this requirement fully, additional basic officer training should be given on a generalized, dynamic ship-control trainer with a malfunction-insertion capability.

The current practice of upgrading IC electricians and forward auxiliarymen, or similarly qualified personnel, to BCPO's, presents a special training problem. The best approach is to provide practice on a BCP emergency procedures trainer and a fidelity dynamic ship-control trainer. Early malfunction detection can provide important clues to impending casualties or current casualties and serve as a basis for casualty prevention. It is essential that the BCPO trainees be made aware of these possibilities and that classroom training be given to supplement the trainer practice.

Rudimentary skill can be developed in a generalized, dynamic ship-control trainer. Shipboard training has a drawback in that many malfunctions and practice in full emergency action can not be tolerated. The generalized dynamic trainer is poor in that negative transfer effects will occur with respect to emergency actions essential to recoverability action, such as manual activation of emergency MBT blow and alternate hydraulic system lineups.

c. Requirement No. 2

The second training requirement is: to know the location of components controlled and/or operated from the BCP. This is one of the most important requirements for a BCPO. Most of this knowledge probably will be developed on board ship while the enlisted man is qualifying as IC electrician or forward auxiliaryman. When these enlisted men are in the process of being upgraded, it is essential that classroom training be given to supplement their previous shipboard experience.

As an additional requirement, a BCP emergency procedures trainer is recommended; this device will include an operable replica of the BCP with an animated display of the system to show conceptually what subsystems and major components are indicated and/or controlled at the BCP. Such a device is needed for training both officers and enlisted men. The importance of this knowledge cannot be overemphasized: it is the BCPO who is expected to communicate and localize any malfunction associated with the systems controlled and monitored at the BCP; and, for effective casualty control, he must have this knowledge.

d. Requirement No. 3

The third training requirement is: to understand the effect of each malfunction on system(s) and ship operations. This requirement is very closely related to the preceding requirement and the same training approach applies. In addition, training should be provided for basic officers to develop supervisory and control capabilities.

The most effective approach at this level is a generalized dynamic ship control trainer combined with classroom instruction and demonstration on the BCP trainer. Shipboard instruction should be given toward satisfying this requirement during the basic officer ship-training tour. Additional officer training should be supplied at the intermediate level in the form of high-fidelity dynamic training and a film, both of which are related to the training requirement in terms of the trainee's class of submarine. Further sharpening of officer skills is possible by including the malfunction and effects on ship's systems in the high-fidelity, dynamic ship-control trainer.

e. Requirement No. 4

The fourth training requirement is: to understand and implement alternate methods or modes, if available, for accomplishing each ship system function. This requirement is fulfilled by developing individual and team knowledge and skills in enlisted men. BCPO training is envisioned as substantially classroom training, with practice on a BCP emergency procedure trainer and on a high-fidelity, dynamic ship-control trainer. BCPO shipboard experience is essential and applicable, but practice is required in emergency actions that cannot be safely introduced on the ship.

For officers, classroom aids are needed in basic training, and a film, integrated with the film of Requirement No. 3, above, would be useful to develop individual knowledge in the intermediate level of training. Practice on a high-fidelity ship-control trainer is required to develop individual and team skills in ship control and decision making.

f. Requirements No. 5 and 6

The fifth training requirement is: to report malfunctions to the OOD and DO. This is closely related to the sixth requirement: to direct local watchstanders to take corrective action via the most direct communications system.

These two requirements indicate a need for training the BCPO to be an unusually effective communicator. Thus he requires instruction in correct procedures, phraseology, function, and location of watchstanders; in local emergency actions that can be taken by

local watchstanders; and in equipment at those locations. Classroom aids and film animation should be used in this phase.

For advanced skills, practice on a communications procedural trainer is needed. Practice in advanced individual skills should be provided, as at present, aboard ship.

Officers also need to practice communications; their training can begin at the basic level with communication procedural training, using classroom aids and films as recommended for the BCPO. As the officer advances, communications practice should be integrated with his training up to and including the high-fidelity, dynamic ship-control trainer.

g. Requirements No. 7 through 9

The following three training requirements for local personnel are treated in combination: to detect malfunctions based on local indications, to understand how local components affect total ship systems and ship operations, and to shift to alternate modes of operation and/or isolate components/systems as directed by senior control stations or as required in a casualty situation.

The basic-enlisted-level classroom instruction should include course content and aids, for example, training-aid booklets dealing with these items supplemented by a demonstration using the BCP emergency procedures trainer. Also at the basic enlisted level, shipboard visits would be of considerable value in learning the location and appearance of potential component failures and the location and mode of operation of panels and other devices used in emergency actions. The system effects of malfunctions can be presented on the generalized basic dynamic ship-control trainer.

It is important that basic enlisted men have as much training in normal systems operation as possible, for it is by knowing normal systems operation that the local watchstanders will be able to detect abnormal operation. As in many of the requirements, polished skills cannot be developed until the basic submariner is assigned to a ship. Hence, at the intermediate level, additional instruction directed toward the trainee's assigned class of ships should be given to satisfy these requirements. The best method of training for the local watchstander is to fulfill his ship qualification and watchstander qualification requirements.

Training similar to that for local personnel should be presented to the transitional officer and can also be integrated with officer shipboard training. A film and/or animated schematics treating system effects of malfunctions on local levels is worthy of consideration. For training in detection, classroom aids in the form of charts, slides, and typical components should be available.

h. Requirement No. 10

The tenth training requirement is: to report changes in status to control or maneuvering by local personnel as appropriate, via the most direct communications system. Training approaches needed for this requirement are the same as those described for Requirements No. 5 and 6, above.

SECTION IV
RESULTS

Subsection Five
Simulation Requirements Analysis

The training method analysis developed the need for training aids and devices that would provide the means of satisfying the training requirement as determined in the training requirement analysis. These aids and devices are described and discussed in Section V.

The characteristic requirements of new dynamic ship control trainers are among the results of the simulation requirements analysis. These recommended characteristics (given in Appendix F) are for the dynamic ship control trainer required to provide advanced team ship casualty control training. The trainer characteristics are intended to be used as trainer simulators for both the SSN and SSBN types and other classes of submarines. Flexibility is a recommended feature but would not be mandatory if it should prove to be undesirable from the user's standpoint.

Some other pertinent facts in Appendix F are recommended characteristics that provide for a device of higher fidelity than is presently available. Recommendations include removal of the operator console from the platform, a study regarding the addition of collision impact, utilization of TV recording for scoring of problems, and simulation of the AMC system.

SECTION V
DISCUSSION

Subsection One
Dynamic Ship Control Trainers

1. GENERAL

Dynamic ship control trainers are required at all levels of casualty control training, as indicated by the training methods analysis. A difference in complexity exists, however, in the dynamic trainer required for each level. The differences are a function of training level, trainee, nature, and extent of casualties being presented, and the capability to accept future changes of ship systems or hull modifications. The dynamic trainer for basic training requires a relatively gross simulation when compared with the faithful simulation device that must be employed in intermediate and advanced team training. The differences vary over a wide range but do not present as serious a problem as appears at first glance. Because of the unique simulation approaches that were formulated in determining the trainer characteristics for each level, it is technically feasible to handle the range of differences.

To present these simulation approaches and provide an understanding of the additional concepts, an introductory discussion of a submarine command and control simulator trainer and its computer complex are presented in this subsection.

2. SUBMARINE SIMULATOR AND ITS COMPUTER COMPLEX

The purpose of differences of complexity in simulation in dynamic ship control devices is to impart different levels of casualty control training. Each device consists of a simulated submarine control room, a trainer operator console, and a computer complex.

The simulated control room includes a steering and diving station and a ballast control panel (BCP). The trainer operator console contains controls and indications necessary for controlling the problem, monitoring the trainee's control actions, and monitoring the ship response to both the trainee's actions, and the operator inputs. The computer complex contains the mathematical model, logic, and input-output equipment to simulate the submarine. The computer may be analog, digital, or hybrid, with the understanding that similar logic and input-output equipment will always be required. The computer is intended to be composed of general-purpose computer hardware components.

The characteristic requirements of simulator training devices are defined as the delineation of features necessary to provide the

simulated shop control actions, ship responses, and ship casualties that are required of the device, including the degree and manner of their simulation. These characteristics are necessary to satisfy the training requirements resulting from the requirements and methods analyses.

If one of the three parts of the simulator, that is, simulated control room, operator console, or computer complex, were selected to typify all the characteristic requirements of the device, it would be the computer complex. The computer complex reflects these characteristics, since it includes the imputs and outputs that relate to the trainee's and operator's controls and indications. Therefore, the computer complex will be discussed to show how the recommended characteristics apply to the device. Subsequently, factors such as completeness, complexity, fidelity, flexibility, and cost of these devices can be weighted more readily by examination of the characteristics in the computer complex. The submarine hydrodynamic characteristics constitute a significant portion of the computer complex, while the control systems combined with the contemplated casualties make up another portion.

These portions of the computer complex can be considered to be independent, as shown by the dashed line in the block diagram of the computer complex in Figure 4. This independence will be made more apparent as this discussion progresses. The hydrodynamic portion of the computer complex, as shown in Figure 4 has inputs from the ship's system portion. These inputs are the specific ship parameters that the trainee and trainer operator can control: namely, the thrust (rpm), the amount and distribution of water in the individual tanks in the trim, main ballast, and negative or hovering tank systems; control surface position (planes and rudder); trim condition control; sea state; flooding rate; flooding location; and collision impact forces and moments. The outputs from the hydrodynamic portion are the depth of the center of gravity of the ship, depth rate, ship's speed, pitch angle, roll angle, and rate of change of heading.

The submarine hydrodynamic equations are shown in Figure 5. It is not intended to go into the deviation of the equations of Figure 5, but the equation term effects will be discussed as they relate to the computer complex. The equations are a version of a complete set of equations describing the motion of a submarine. The six differential equations are (1) axial force, (2) vertical force, (3) pitch moment, (4) lateral force, (5) roll moment, and (6) yaw moment. The six variables of these equations u, v, w, p, q, and r are, respectively, axial, lateral, and vertical velocities and roll, pitch, and yaw rates. The "dot" terms are their time deviations. The auxiliary relations across the bottom of Figure 4 relate the euler angles, depth rate, and ship speed to the six truly variable quantities described by the six equations. A dotted line drawn through the six equations separates these controlling the hydrodynamic effects from the variables controlled by the operator and trainee.

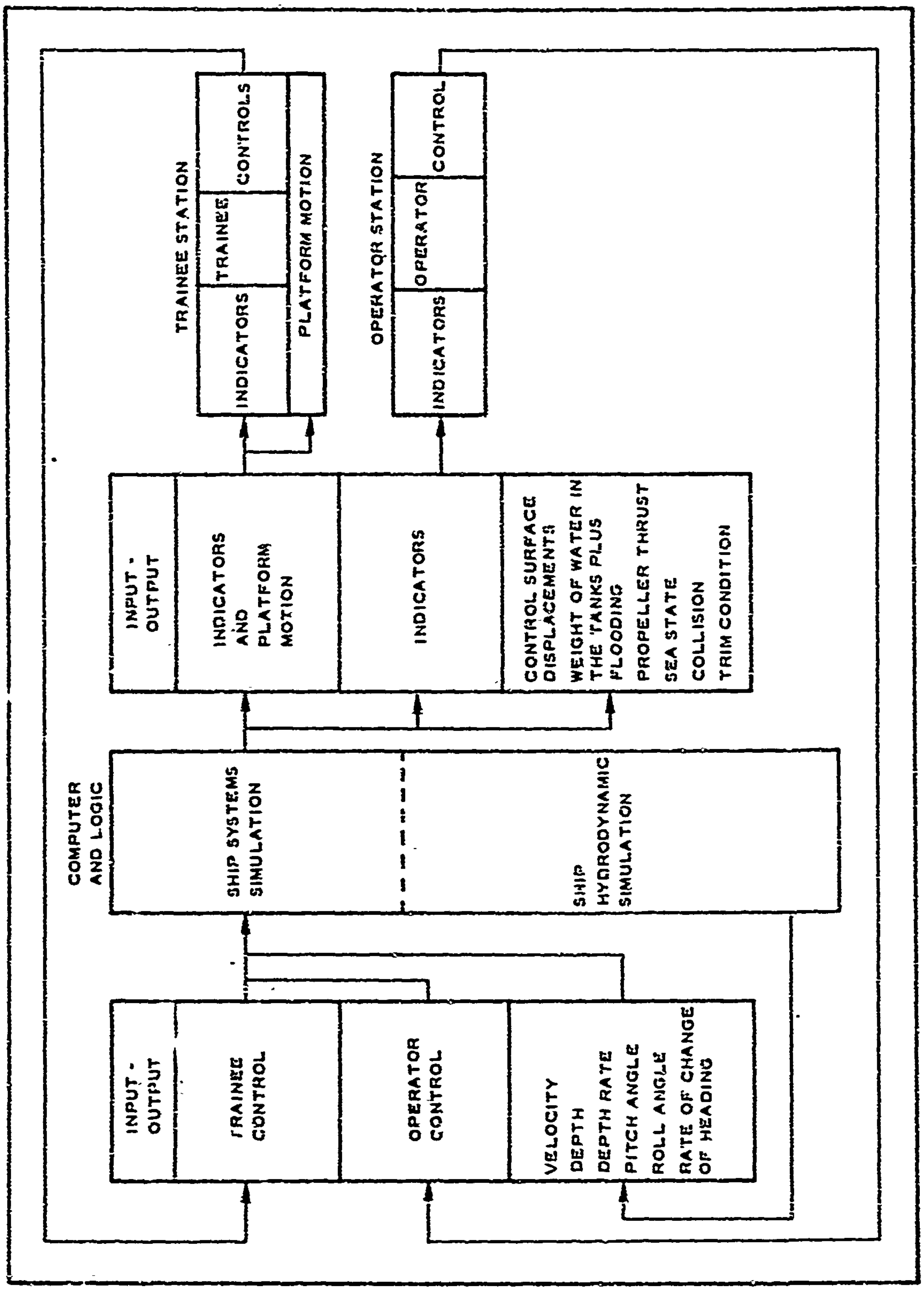

Figure 4 - Computer Complex

The purpose is to show the hydrodynamic damping and cross coupling terms on the left of the dotted line while the operator and trainee controllable terms are on the right.

The differential equation of the axial force (when integrated produces axial velocity), Equation 1 of Figure 5, has the righthand terms lettered A through F. The terms are used to determine typical ship effects, both individual and in combination. These are related in Table II. The terms like C and D can be incorporated in alternate degraded fashion, as noted in entries 2 or 7 of Table II. This is not a complete table, since many more combinations could be thought of as typical. The table does indicate there are such alternatives as the solution of the differential equation by normal integration or by degradation to algebraic format not requiring integration. An extra variable multiplication allows for differences in acceleration and deceleration; propellor thrust can be controlled by either trainee (engine order control) or operator (variable only). Each of these alternatives has hardware implications; integration is or is not required. An extra multiplication is or is not required. The trainee does or does not have an engine order control. Each of the seven entries in Table II is quite different, and for each one, usually, a relatively similar entry would be required in the other five equations. With the latter in mind, a better mental picture would be obtained of the total simulation requirement and alternatives. One other matter for consideration is the comparison of the first entry of Table II and Equation 2 through 6 of Figure 5. There are over 20 terms that have either u, U, uU, u^2, or U^2, which would not require variable multiplication if operator control of ship speed were limited to a small range.

A further explanation of the factors of the terms of the equations applicable to Table II and Figure 5 are as follows. The m, m_1, m_2, and m_3 coefficients are variable coefficients that are functions of the term $(W_o + \sum W_{Ti})$. The factor $(1/2\rho l^2)$ is one half of the water density times the square of the ship length. The hydrodynamic coefficients are the subscripted prime letters.

These hydrodynamic coefficients are either single or multiple-valued constants. They are usually discretely changed by logic equipment and depend on the condition existing when the change is made. All these coefficients are dependent on depth. For example, all the fairwater plane coefficients are zero when the ship is on the surface and remain zero until such a depth is reached that the planes are fully submerged. The additional overall requirement of faithful simulation of surfacing and diving qualities would require that logic be provided to change the coefficients at the appropriate depths. If only submerged operation is required, this logic is not required.

The number of systems, number of modes, and the contemplated

SEC

HYDRODYNAMIC EFFECTS → | OPERATOR/TRAINEE CONTROLLABLE

1. AXIAL VELOCITY (AXIAL FORCE)

$$m_1\dot{u} = \overbrace{m_2 rv}^{A} - \overbrace{m_3 qw}^{B} + \tfrac{1}{2}\rho\ell^2 uU\Big[\overbrace{X'_u}^{C} + \overbrace{X'_{\delta r}(\delta r + \beta r)^2\cos\beta r + Y'_{\delta r}(\delta r + \beta r)\sin\beta r}^{D} + X'_{\delta s}\delta s^2 + X'_{\delta l}\delta l^2\Big] - \overbrace{(W_o + \Sigma W_{Ti} - \Delta)\sin\theta}^{E} + \overbrace{T_p + T_s}^{F}$$

CROSS COUPLING · DAMPING · RUDDER · STERN FAIRWATER PLANES · WEIGHT OF WATER IN TANKS PLUS FLOODING · PROPELLER THRUST

2. VERTICAL VELOCITY (VERTICAL FORCE)

$$m_3\dot{w} = \underbrace{mqu - m_5 pv}_{\text{CROSS COUPLING}} + \tfrac{1}{2}\rho\ell^2\Big(\underbrace{Z'_{w|w|}w|w|}_{\text{DAMPING}} + \underbrace{Z'_o U + Z'_w wU + Z'_q qU + Z'_v v^2 + Z'_{rv} rv + Z'_r r^2}_{\text{CROSS COUPLING}} + \underbrace{Z_{\delta s}U^2\delta s + Z'_{\delta l}U^2\delta_l}_{\text{STERN FAIRWATER PLANES}}\Big) + (\underbrace{W_o}_{\text{WEIGHT OF HULL}} + \Sigma W_{Ti} - \underbrace{\Delta}_{\text{DISPLACEMENT}})\cos\theta\cos$$

3. PITCH MOMENT

$$I_{yy}\dot{q} = \underbrace{(I_{zz} - I_{xx})pr}_{\text{CROSS COUPLING}} + \underbrace{\tfrac{1}{2}\rho q\left(C_1|q| + C_2\frac{w^2}{|q|} + C_3\frac{w^4}{q^2|q|} + C_4|w|\right)^{?}}_{\text{DAMPING}} + \tfrac{1}{2}\rho\ell^3\Big(\underbrace{M'_o\bar{U} + M'_w w\bar{U}}_{\text{CROSS COUPLING}} + \underbrace{\ell M'_q q\bar{U}}_{\text{DAMPING}} + \underbrace{M'_{w|w|}w|w| + M'_v v^2 + \ell M'_{rv} rv + \ell^2 M'_r r^2}_{\text{CROSS COUPLING}} + \ldots$$

4. LATERAL VELOCITY (TRANSVERSE FORCE)

$$m_2\dot{v} = \underbrace{m_3 pw - mru + \tfrac{1}{2}\rho\ell^2\Big[(Y'_r + KY'_{\delta r})vU}_{\text{CROSS COUPLING}} + \underbrace{Y'_{vv}v|v|}_{\text{DAMPING}} + \underbrace{\ell Y'_p pU + \ell\left(Y'_r + \frac{K}{2}Y'_{\delta r}\right)rU}_{\text{CROSS COUPLING}} + \underbrace{Y'_{\delta r}U^2\delta r}_{\text{RUDDER}}\Big] + \underbrace{(W_o + \Sigma W_{Ti} - \Delta)\cos\theta\sin\phi}_{\text{WEIGHT OF WATER IN TANKS PLUS FLOODING}}$$

5. ROLL MOMENT

$$I_{xx}\dot{p} = -\underbrace{(I_{zz} - I_{yy})qr + \tfrac{1}{2}\rho\ell^3(K'_v vU + K'_{vv}v|v| + K'_p pU + K'_r rU + K'_{uu}u^2)}_{\text{CROSS COUPLING}} + \underbrace{C'_F p}_{\text{DAMPING}} - \underbrace{(W_o Z_{bt} + \Sigma W_{Ti}Z_{Ti})\cos\theta\sin\phi + \Sigma W_{Ti}Y_{Ti}\cos\theta\cos\ldots}_{\text{MOMENT DUE TO WATER IN TANKS PLUS FLOODING}}$$

6. YAW MOMENT

$$I_{zz}\dot{r} = -\underbrace{(I_{yy} - I_{xx})pq + \tfrac{1}{2}\rho\ell^3\left[(N'_r + KN'_{\delta r})vU + \ell N'_p pU + \ell\left(N'_p + \frac{K}{2}N'_{\delta r}\right)rU\right]}_{\text{CROSS COUPLING}} + \underbrace{\tfrac{1}{2}\rho r\left(C_1|r| + C_2\frac{v^2}{|r|} + C_3\frac{v^4}{r^2|r|} + C_4|v|\right)^{?}}_{\text{DAMPING}} + \underbrace{\tfrac{1}{2}\rho\ell^3 N_{\delta r}U^2\ldots}_{\text{RUDDER}}$$

AUXILIARY RELATIONS

EULER ANGLES

$$\dot{\theta} = q\cos\phi - r\sin\phi \approx q - r\sin\phi$$

$$\dot{\phi} = p + q\sin\phi\tan\theta + r\cos\phi\tan\theta \approx p + r\cos\phi\tan\theta$$

$$\dot{\psi} = [q\sin\phi + r\cos\phi]\,/\cos\theta$$

DEPTH RATE $\dot{z} = -u\sin\theta + v\cos\theta\sin\ldots$

TOTAL VELOCITY (SHIPS SPEED) $U = \sqrt{u^2 + v^2 + w^2} \approx \sqrt{u^2\ldots}$

TRAINEE CONTROLLABLE

$$t_{C_1} = C_2 = C_3 = 0 \qquad |w| \geq \frac{s\ell}{2}$$

$$C_4 = 0 \qquad |w| < \frac{s\ell}{2}$$

$$\underbrace{- (w_o + \underbrace{\Sigma w_{Ti}}_{\text{WEIGHT OF WATER IN TANKS PLUS FLOODING}} - \Delta) \sin\theta}_{Z} + \underbrace{T_p + T_s}_{\text{PROPELLER THRUST}}$$

WATER

$$t_{C_1} = C_2 = C_3 = 0 \text{ WHEN } |v| > \frac{r\ell}{2}$$

$$C_4 = 0 \qquad \leq \frac{r\ell}{2}$$

$$\underbrace{{}^2\delta s + z'_{\delta f} u^2 \delta_f)}_{\text{FAIRWATER PLANES}} + (\underbrace{w_o}_{\text{WEIGHT OF HULL}} + \Sigma w_{Ti} - \underbrace{\Delta}_{\text{DISPLACEMENT}}) \cos\theta \cos\phi + \underbrace{K_7 T_p + K_8 T_s}_{\text{PROPELLER THRUST}}$$

$$\underbrace{q\bar{U}}_{\text{DAMPING}} + \underbrace{M'_{ww} w|w| + M'_v v^2 + \ell M'_{rv} rv + \ell^2 M'_r r^2}_{\text{CROSS COUPLING}} + \underbrace{M'_{\delta s} \bar{U}_{\delta s} + M'_{\delta f} \bar{U} \delta f)}_{\text{STERN FAIRWATER PLANES}} - \underbrace{(w_o z_{bL} + \Sigma w_{Ti} z_{Ti}) \sin\theta - (w_o x_b + \Sigma w x_{Ti}) \cos\theta \cos\phi}_{\text{MOMENT DUE TO WATER IN TANK PLUS FLOODING}} + \underbrace{MW}_{\text{SEA STATE}}$$

$$\underbrace{u^2 \delta r}_{\text{RUDDER}} \Big] + \underbrace{(w_o + \Sigma w_{Ti} - \Delta) \cos\theta \sin\phi}_{\text{WEIGHT OF WATER IN TANKS PLUS FLOODING}}$$

$$\underbrace{+ \Sigma w_{Ti} z_{Ti}) \cos\theta \sin\phi + \Sigma w_{Ti} y_{Ti} \cos\theta \cos\phi}_{\text{MOMENT DUE TO WATER IN TANKS PLUS FLOODING}} + \underbrace{Q_p - Q_s}_{\text{TORQUE DUE TO PROPELLER}} + \underbrace{KW}_{\text{SEA STATE}}$$

$$\underbrace{+ C_2 \frac{v^2}{|r|} + C_3 \frac{v^4}{r^2 |r|} + C_4 |v|) }_{\text{DAMPING}}{}^{t} + \underbrace{\frac{1}{2} \rho \ell^3 N'_{\delta r} u^2 \delta r}_{\text{RUDDER}} + \underbrace{(w_o x_b + \Sigma w_{Ti} x_{Ti}) \cos\theta \sin\phi + \Sigma w_{Ti} y_{Ti} \sin\theta}_{\text{MOMENT DUE TO WATER IN TANKS PLUS FLOODING}} + \underbrace{K_{11} T_p + K_{12} T_s}_{\text{TORQUE DUE TO PROPELLER}}$$

DEPTH RATE $\dot{z} = -u \sin\theta + v \cos\theta \sin\phi + w \cos\theta \cos\phi = -u \sin\theta + w \cos\theta \cos\phi$

TOTAL VELOCITY (SHIPS SPEED) $U = \sqrt{u^2 + v^2 + w^2} = \sqrt{u^2 + w^2}$

Figure 5 - Hydrodynamic Equations

2

TABLE II - HYDRODYNAMIC EFFECTS REQUIRING TERMS OF EQUATION 1, FIGURE 5

No.	Hydrodynamic effect required	Terms of equation
1	Ship speed must be operator controlled and have no acceleration or deceleration.	Term F is required but is operator controlled. This is denoted by F_o. (F implies trainee control.) The sum of terms (A + B + C + D + E) equals zero and is not needed). $\dot{\mu}$ becomes μ (no integration required). Equation 1 becomes $\mu = F_o$.
2	Ship speed must be operator controlled and have the same acceleration and deceleration.	Term F becomes F_o as above. Term C becomes C/U since u only is needed, not the product uU. Equation 1 becomes $u = C/U + F_o$.
3	Same as 2 but a difference between acceleration and deceleration.	Equation 1 becomes $\dot{\mu} = C + F_o$.
4	Ship speed must be trainee controlled, slowed down in turn, and with rudder activation and difference in acceleration and deceleration.	F_o becomes F. A and δ_r part of D are needed. Equation 1 becomes $\dot{\mu} = A + C +$ (δ_r part of D) + F.
5	Same as 4 but bouyancy effect on ship speed must be shown.	Equation 1 becomes $\dot{\mu} = A + C +$ (δ_r part of D) + E + F
6	Slow down during normal diving and rising, slow down due to stern and fairwater planes, difference in acceleration and deceleration, and trainee control of ship's speed.	Need δ_s and δ_f parts of D. Term B is needed. Equation 1 becomes $\dot{\mu} = B + C +$ $\delta_s + \delta_f$ part of D) + F
7	Ship speed: trainee controlled, same acceleration and deceleration, bouyancy effect, and some slow down due to all control surfaces.	Either Equation 1 becomes $\dot{\mu} = C/U + D + E + F$ or (δ not δ^2 in D denoted $\sqrt{D}$). Equation 1 becomes $\dot{\mu} = C/U + \sqrt{D} + E + F$.

casualties or malfunctions determine the characteristic requirements of the ship systems portion of the computer complex. This portion contains the simulation of the rates and modes of the following: positioning the rudder and planes in response to student inputs, engine order response, main ballast (variable and special tank) control and associated indications, and control actions. Each mode of operation, each malfunction or casualty, and each indication that is operable in each system at the trainee and operator stations add to the characteristic requirements of this portion of the computer complex. Each one of these functions usually adds a relatively large amount to the mathematical model and logic.

To show this in a more graphic way, a stern plane system simulation will be discussed. First, for a simple simulation. Then for a more complicated simulation. The characteristics of the simple system are (1) control column will position the stern planes at a known rate and (2) plane position will be indicated to the operator and trainee (trainee will have both normal and auxiliary indications).

This simple system simulation is shown in Figure 6. The additional characteristics of the complicated system are

1. Simulated hydraulic power (which can be failed) is required in both normal and emergency modes.
2. Trainee will be able to select and operate the stern planes in normal and emergency modes.
3. In normal and emergency modes plane positioning rates are different.
4. Operator can fail the system in each mode of operation and each of the trainee's indications.
5. Trainer may turn hydraulic system on or off.

These two types of simulation are quite different and each additional requirement adds to completeness, complexity, fidelity, etc. of the computer complex (weight factors) as indicated in Figure 6.

The fact that the trainee and operator control actions and indications that are related to the requirements of the computer complex provides a basis for analyzing or weighing the effect of simulating a function of the complexity and cost of the computer complex, and by implication, a basis for estimating the completeness, complexity, cost, and fidelity of the trainer.

The above discussion was not intended to be an accurate, actual ship system simulation, but an example possessing some of the

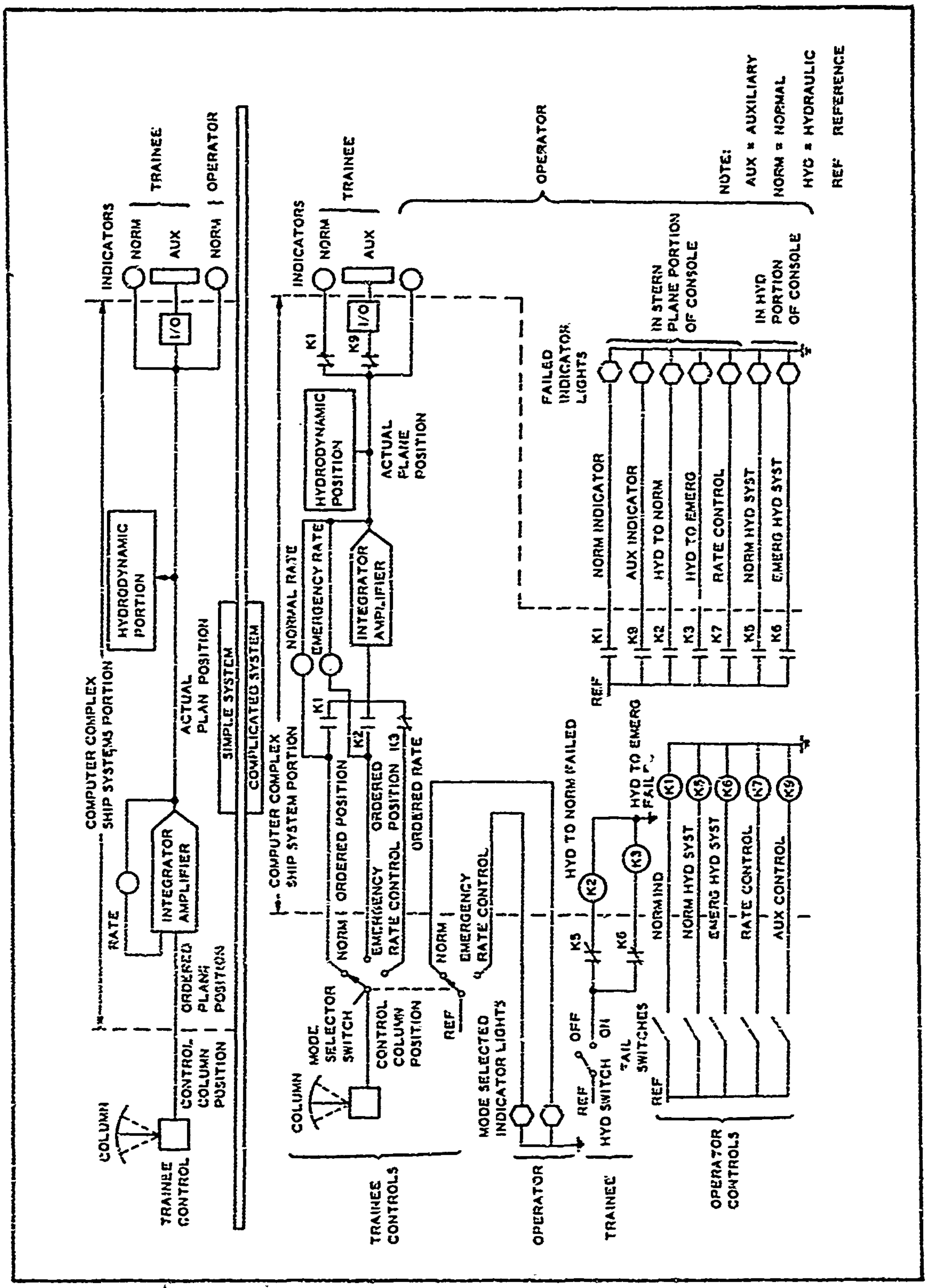

Figure 6 - Stern Plane Systems

representative operational qualities and potential failures provided in simulation. The inputs and outputs from the hydrodynamic portion of the computer complex usually do not change. However, if the trainer operator, when inserting a failure, has the ability to position the stern planes to any position in the normal range of plane movement or if hydraulic plant operation includes representative accumulator functions and malfunctions, additional type requirements would again add to the weight factors.

It was the intent of this computer complex discussion to emphasize that there is independence between the hydrodynamic and ship's system portions of the computer complex and that the weight factors are directly related to behavior functions to be exercised and their fidelity. It is also true that the presentation of each additional effect can add considerably to the mathematical model and logic of the dynamic ship control trainer. The additional mathematical model and logic data will result in an increase in the total program, which can be directly related to either the computer and logic hardware for the analog approach or the computer hardware and software for the digital approach.

3. ALTERNATE APPROACHES

In determining the characteristic requirements of the new trainers and determining the capabilities of the existing trainers, the concept of session banding was conceived. This concept will require additional study. In the session-banded training concept the trainer would be programmed and set up for a specific training session to simulate a limited ship-operating envelope, for example, depth band, and the specific ship system malfunctions or casualties appropriate to the phase of training and scheduled exercises. The principal application or importance of this concept is mainly of concern in analog approaches.

The existing devices are relatively "fixed" with respect to hardware and functions simulated. The new trainer characteristics of Appendix F identify more hardware and simulation functions (including computer-complex requirements) than any previous device. This is because every function that the device simulates is simultaneously available during each training session. Yet when the device is scheduled for a training session, its scope and purpose is specified, and in almost every session, certain ship systems, system modes, and casualties or malfunctions can be excluded.

As an example, the missile status board of FBM trainers would not be used for a large number of training sessions, and corresponding portions of the computer and logic, which would normally be idle during the session, might be employed for other purposes, for example, where the simulation is not as well simulated as it could be because of the limitations otherwise of the computer complex. This approach would enable the new devices to employ a much

smaller computer complex than the characteristic of Appendix F indicates for the simultaneous availability of all simulated functions as usually practiced in simulator mechanization. The existing trainers are specially wired general-purpose computers (some patchable) and possess the "all-at-once" quality described above. As pointed out in the general discussion of the computer complex, each characteristic provided by existing simulator trainers adds to the completeness, complexity, fidelity, flexibility, and cost. For the ultimate training it is not necessarily desirable to increase all these factors. The banded approach would definitely preserve or might even increase completeness, fidelity, training effectiveness, and flexibility while reducing the complexity and cost.

Some of the disadvantages of the banded approach would be the following. There might be an additional engineering cost of the first such device. Time between sessions might be lengthened due to changing of the band. Fixed limits on the simulated environment training session may produce improper attitudes and anticipations in personnel. If the library of training sessions were too limited, motiviation during training and flexibility in performance afterward on the job to fit changing conditions might suffer, but not if the training program were well-planned. Time would be required to produce new programs for new developments in ship systems design or casualty considerations in the future.

The banding approach has some important advantages:

1. Reduced cost of the devices
2. A large reduction of the computer complex compared with previous methods of mechanization if analog-type computers are used
3. Increased flexibility for adding simulation of equipment and modes of operation
4. Capability for increased fidelity of simulation using the same size computer complex as used in existing devices
5. Standardization of training and provision of a fixed base for evaluating different crews' performance

The approach is particularly applicable to patchable types of computer complexes used in existing simulator trainers. This approach should be studied further to determine optimum means of implementation. The study would include

1. Definition of bands to be used and program requirements
2. Development of a method for changing bands between training sessions

3. Development of computer requirements for both new and existing dynamic ship control trainers.

In the latter part of the proposed study, consideration would be given to general-purpose versus specially wired general-purpose computers and to digital and hybrid types of computers. One of the main objectives would be to maximize flexibility.

An economical approach to malfunction insertion is to use common logic and hardware for inserting malfunctions and system shutdown. This simplifies the logic of malfunction insertion in a training device (see Figure 6 and the requirements of the complicated stern plane system discussed in the general simulator computer complex discussion). Compare that approach to the approach shown in Figure 7 and note the simplification by the elimination of relays 2, 3, 5, 6, 7, and the corresponding indicator lights on the trainer operator console. Note that one of the relays was moved over to the rate mode and one was changed to operate on either plus or minus reference voltage, and the variable control and the selector were added to cover an additional requirement not in Figure 6. This approach reduces cost and complexity. With the same amount of hardware and logic that would otherwise be used, fidelity is increased and the number of functions to be simulated can be expanded. This approach was believed to have enough merit to be included in the new trainer characteristics described in Appendix F. The approach would also apply to the analog portion of existing or future hybrid computers.

4. NEW TRAINERS

a. General

As pointed out in the results of the training method analysis (Section IV, Subsection Four) there are different levels of fidelity for dynamic ship control trainers needed for the various levels of casualty control training. The new devices considered below are ones that would be used for advanced team casualty control training. (See Appendix F for recommended ship control trainer characteristics.) At the time of such training the ship control team is assumed to be assigned to an SSN or SSBN submarine.

Complete and adequate advanced casualty control training of ship control teams is of such a nature that the team cannot be trained by shipboard drills in the critical casualties and system malfunctions without the high risk of losing the ship and/or a hazard to the crew. This dictates that the advanced ship control trainer must provide a suitably realistic simulated environment that includes these extremely hazardous situations (see Subsection Four, Section IV, and Section V). Subsection Three of Section IV identifies training requirements that have to be met. Examples include:

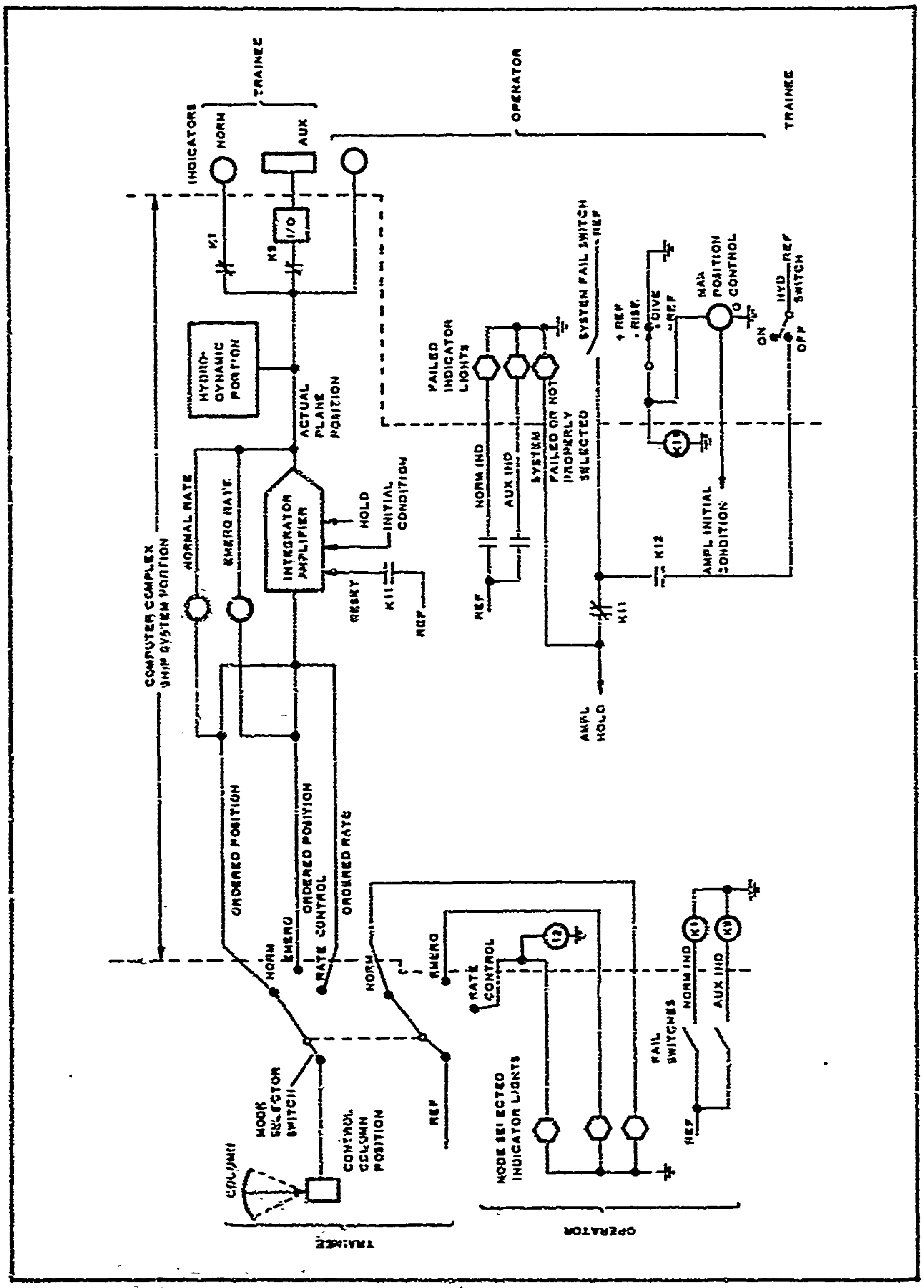

Figure 7 - Stern Plane System Simplified by Malfunction Combination

1. Development of a capability to rapidly switch mental sets from that appropriate for normal, AMC, or even one-man control to that which is appropriate for emergency action, including prompt and discriminating reaction to abnormal indications or abnormal ship motion
2. Development of a perceptual motor capability to shift to alternate modes of operation such as rate control and locating (emergency) the manual control of the planes or rudder
3. Development of the ability to analyze and maintain trim control so that cues of malfunctions from indicators and the ship-feel are not compounded with a heavy condition, down angle, up angle, or list due to an improper or unknown trim

These three training requirements contribute to the understanding of trim as a function of control surface deflection. The recommended trainer will provide crews with an understanding of trim as a function of system operation and interactions. For example, the AMC may fail in such a way as to indicate an out-of-trim condition. If both stern and fairwater planes are in rate control, the team can readily detect an out of trim condition of 1000, or 5000, or 20,000, or 80,000 lb.

The advanced ship-control casualty-control trainer must provide the capability of presenting complex casualty situations with known inputs (presentation of effects and ship/systems operating characteristics), the capability for personnel to exercise their judgment and emergency reactions, and provide an accurate knowledge of the results (feedback) both as the training problem progresses and at the end of the exercise or session. The trainer must be capable of presenting casualty training problems with the following types of conditions:

1. A recoverable size hole (shear) in a pipe aft
2. An initial watchstander report 2 to 60 sec after the start of flooding
3. Ship in operation at deep submergence at 8 to 15 knots
4. Depletion of air banks after a fixed time period of continuous emergency MBT blow
5. MBT No. 1B and No. 2B blow valves inoperative throughout problem

The problem mentioned would provide the instructor an opportunity to train and evaluate the members of the ship control party in what they should do, the commands and responses that would be given

(communications), team action and effectiveness, and ship recoverability characteristics as related to control team judgment and action. These considerations typify those that went into the identification of the advanced ship control trainer simulator characteristics.

Although different ship control trainers are required for SSN's and SSBN's, economy will be gained by making the trainer for each adaptable to several (or all) classes within each of the two types of ships. This will require built-in flexibility. Flexibility in the computer complex sufficient to permit changes representative of differences in classes of ships is discussed in Item 2 of Subsection One, Section V. Current analog, digital, and hybrid computers do not require much time to change and verify programs. There will be a requirement to change some panels of the trainer so that controls and displays are arranged in the same way as in the class of ships to which the trainers are assigned. This is necessary to avoid negative transfer of training effects for emergency procedures, as discussed later in Subsection Four, Section V. Use of the CIP versus the conolog display is discussed subsequently in Subsection Two of Section V. Physically changing the panels to reflect the proper class of ship for trainees will not be impractical or unduly expensive and time consuming. The principal requirements will be for spare wires and alternate panel mounting provisions. Provisions for changing BCP panels to reflect differences between SSN's and SSBN's would be more extensive because of different console configurations but practicable on a semipermanent basis. Similar considerations hold true for emergency steering controls and pilot transfer hydraulic control valves for the fire-water planes.

At this point it is appropriate to discuss the "weight factors" mentioned previously. A first glance at the recommended characteristics in Appendix F are staggering, but this is due only to traditional concepts of mechanization of the computer complex. The traditional approach is additive in regard to the completeness, complexity, fidelity, flexibility, and cost. By additive is meant each of the weight factors would be directly increased by each requirement contained in the recommended trainer characteristics. This was pointed out in the computer complex discussion. (See Section V, Subsection One.) One of the last of the recommended characteristics is the malfunction combination discussed in Section V, Subsection One, Item 2, and the preceding typical training problem description.

Session banding implementation of the computer complex, if existing trainers are modified, would provide the possibility of reducing complexity and cost while preserving completeness, fidelity, and flexibility. Related items not previously discussed are reliability and ease of maintenance. These factors might also be increased by application of the session banding concept. Other items, although

primarily applicable to new ship control trainers (simulation of collision effects, the operator's console, and scoring) are discussed below.

b. Collision Consideration

As pointed out in Submarine Safetynote, 8 June 1965, " . . . collision remains the greatest single threat in major submarine casualties with an incident rate of 38 percent."

Present training devices provide for flooding or plane jamming as a result of collision, but there is no impact due to collision. The need for this requirement is not substantiated by either the training requirements or training methods analyses, but based on a cursory examination it is believed that inclusion of collision effect (impact) in dynamic ship control trainers should be investigated.

The physical principles of collision and analysis of the mechanization of the submarine motion equations in existing devices indicate that the ship reactions could be quite easily programmed and be independent or coincident with flooding and/or jamming of the planes. Collision concerns momentum and is assumed to be elastic. The law of conservation of momentum covers the collision of one moving body with a moving or stationary body, which can include collision as well as bottoming reactions. Figure 8 shows a collision of two moving bodies where the mass and vectors of the velocity of the body colliding with the simulated submarine are known. If the case of two bodies of the same mass is assumed and the vectors (forces) and moment terms are as shown in Figure 8, the mechanization would be relatively simple. These forces and moments would be applied for a short interval of time to all or part of the six equations simultaneously to produce the heave, slow down, slide slip, pitch, roll, and yaw that would be encountered in a collision. The relative mass and velocities would be set by the trainer operator and at the time of collision, with or without the other casualties, he would insert the collision effects by pressing a momentary button.

Realistic noise of a collision might be activated at the same time. Implementation of collision effects is believed to be desirable and easily implemented for casualty control training.

c. Instructor/Operator's Console

Throughout the discussions of dynamic ship control trainers, the instructor console was referred to as the operator's console. The visits to the training facilities, and the documentation showed that, on the existing devices, with the exception of Device 21B20 (not Device 21B20a), the console was on the platform and that during training sessions, the crew, additional personnel (observers or alternates), and the instructor rode the platform. With the operator's console in such close proximity to the trainee positions, the

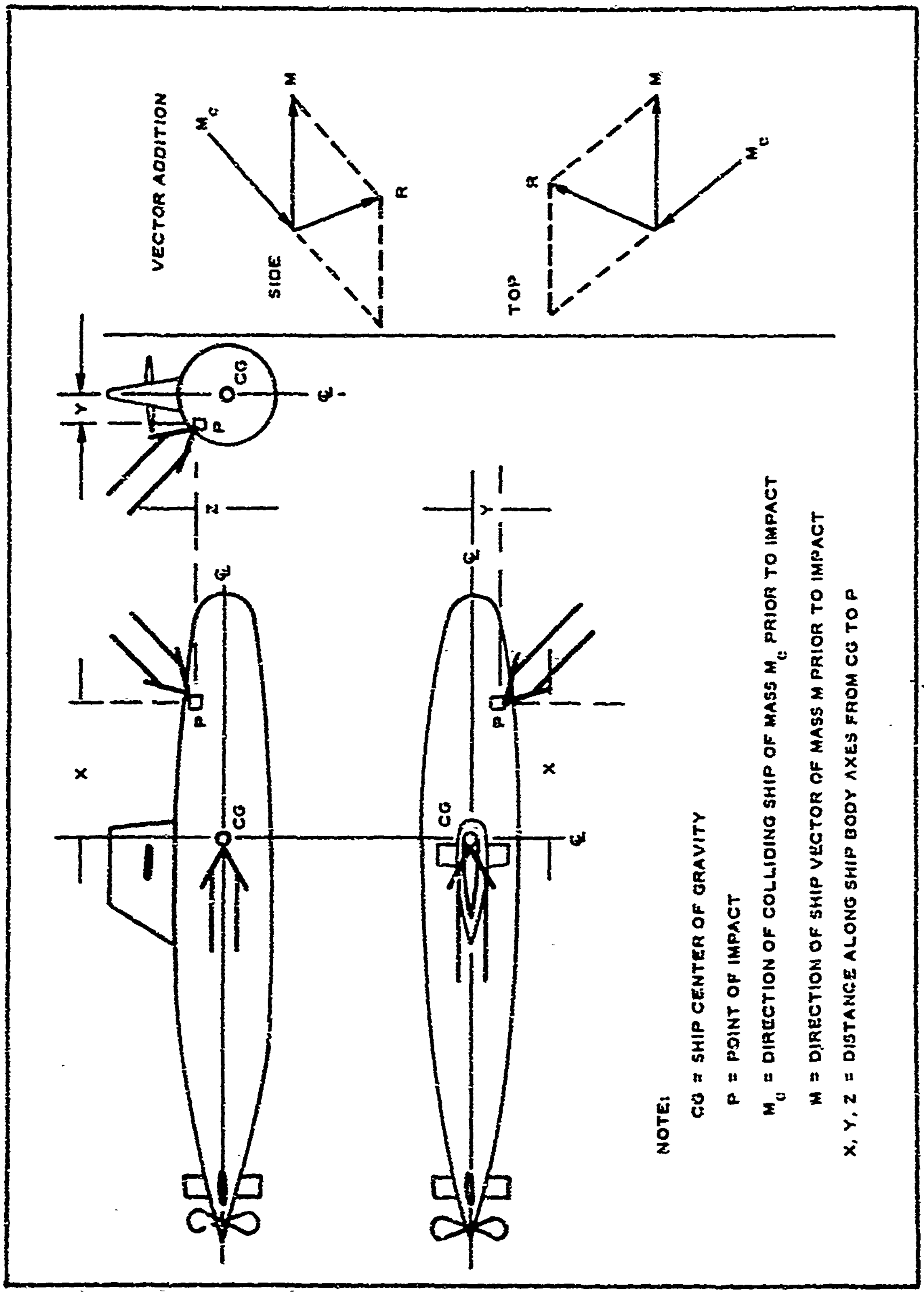

Figure 8 - Collision Diagram

element of surprise is often lost when the operator inserts system malfunctions and casualties. For these reasons, it is recommended that the operator's console of future dynamic trainers be located off the platform, in the adjacent critique/observer area, at approximately the same level (height) as the trainee station. The instructor could ride the platform and the operator would be in control of the problem. This would simplify the facility wiring to the trainer platform by the reduction of the number of wires required in the cable that must be flexible due to the platform motion. It would also improve the training environment. The cost would probably be too prohibitive for removal of the consoles on platforms of existing ship control trainers.

d. Scoring

The existing facilities have a multichannel, analog-type recorder for scoring and are usually in the computer complex. The scoring equipment should be controlled at the operator's console and be accessible to the instructor. Scoring features should also include the TV recording-playback feature (discussed in Section IV, Subsection Four, Item 4) in the immediate vicinity of the console. This is one purpose for locating the observer/critique facilities in the operator's area adjacent to the operator's console. The TV playback display would be operator/instructor controlled and be located on the trainer platform near the overhead between the BCP and diving stand. The TV system would have to be designed so that no RFI transmission would occur because of the classified nature of some of the discussions.

5. EXISTING TRAINERS

During this study most of the existing trainer facilities were visited and limited facility documentation and evaluations were examined. The existing ship control trainer facilities have all had some degree of modification to incorporate a flooding capability, and there are a number of other modifications that are in the process of being made. The existing dynamic ship control trainers are of three distinct types, the FBM (diving stand and BCP, the SSN (diving stand and BCP), and general ship control (diving stand only).

One part of the study was to determine which of the characteristics identified in Appendix F and not presently incorporated in existing devices, could feasibly be incorporated. The investigation determined that the general diving stand type devices would not warrant any additional casualty control modification. The reason for this is that these devices presently possess sufficient casualty control features to be consistent with the training value that can be gained in view of their greatly simplified mode of operation. There are two different types of generalized dynamic ship control device trainers: Device 21B20a and Device 21B56. The "Training Effectiveness as a Function of Trainer Complexity" study by J. Newton,

Electric Boat Division, Groton, Connecticut, was conducted during the time between the delivery of these two devices. Device 21B20a was characterized by adding a "joystick" attachment to Device 21B20, a diesel SS563 class trainer. The computer of Device 21B20 and Device 21B20a was a common element to both devices and quite large in relation to that of Device 21B56. Device 21B56 was the first Navy trainer to reflect the findings of the study mentioned above. The computer size, using as a yardstick the ratio of the number of amplifiers, was approximately 10 to 1 for 21B20a to 21B56.

A cost comparison of these two variations of generalized ship control trainers was not made in this study, since no cost data were available. Moreover, Device 21B20a was an existing device modified by the addition of an attachment, and the computer that had been previously purchased was used.

The SSN general ship control trainer is Device 21B56A. The primary difference between Devices 21B56A and 21B56 is the addition of the BCP. This indicates that the ship system portion of the computer complex grew a larger amount than the hydrodynamic portion. The weight and moment computations were added to the hydrodynamic portion, while all the methods (plus the associated malfunctions) of controlling the water in the tanks and determination of the tank fill and empty rates were added to the ship systems portion. The ratio of the number of amplifiers in the computers of Device 21B56A to 21B56 is approximately 2-1/2 to 1. While this device is not much different than Device 21B56, its computer size and patchable nature indicate that by the application of the two alternate approaches to the program, discussed in Section V, Subsection One, Item 2, Device 21B56A, capabilities could be greatly increased in an economical way. This is the reason for not recommending that any additional characteristic be added to Device 21B56A at this time.

This same recommendation applies to the FBM devices, particularly since they have large computers and the same patchable feature as Device 21B56A.

The ratios of the number of amplifiers in the computer for the FBM devices to ship control trainer Device 21B56 and Device 21B56A are approximately 6 to 1 and 2 plus to 1, respectively. The FBM devices have the missile status board and missile associated tanks and their control. They also have more terms in the motion equations of the hydrodynamic portion of their computer complex, but they are not the equivalent of the new device characteristics of Appendix F.

The above evaluations, the training methods analysis, and the generalized training discussion indicate that it is quite feasible to implement the alternate approaches in the mathematical model and logic if additional quantities of existing types of training devices are

procured to realize considerable savings and increased effectiveness.

SECTION V
DISCUSSION

Subsection Two
Special Training Considerations

1. PERSONNEL PRACTICES AND MANNING CONSIDERATIONS

Personnel turnover and reassignment occur at such a sufficiently high rate that SSBN crews beginning a patrol are often limited to two qualified watch sections. SSN crews may suffer an even greater attrition during extended overhaul. Hence, from the viewpoint of casualty control, personnel are under a condition of fatigue, and their capability to react immediately to an emergency is seriously reduced. To qualify as watchstanders, new personnel require an average of up to one-half of the patrol period for learning peculiarities of ship systems. Although this is in conflict with current practice and tradition, it is an area where a need for training ashore is indicated. It is entirely feasible to reduce shipboard training time by using training aids, films, and animated schematics to develop ship control principles, system operating characteristics, and equipment arrangement in shore-based training prior to embarkation.

In general, the personnel assigned as helmsman or sterns planesman are among the least qualified. The problem is that, while the position is highly critical during ship casualties, it does not require as complex behavior or knowledge as is required at other battle stations. In experience, planesman range from one patrol or less to about one year, and their time on trainers currently ranges from one day to one week. Based on observation and interview, the importance of planesmen skills and the need for training are probably underrated from the casualty control standpoint. More training than now given is needed to ensure that planesmen can detect plane and control casualties, distinguish between complex and simple indication modes of failure, and perform the correct emergency responses in the small amount of time available for recovery initiation.

The current practice aboard most SSBN ships is to assign CPO's as DOOW's. A serious problem in this practice is that, while CPO's have many years experience and are well grounded in technical knowledge, they have not been schooled in ship control principles. Thus, there is a need to provide them classroom training and practice on the diving stand as well as team training.

The BCP is the control and monitoring center for a majority of systems vital to safe ship control and recovery from casualties. BCP operation involves time sharing of several complex procedures

and monitoring of a large number of instruments. For proper emergency operation, the BCPO must understand the operating characteristics of the systems controlled and must be able to relate system problems for isolation or local control to the various watchstanders within the ship. In addition, the BCPO, functioning as the COW, is responsible for proper communication and must be ready to take responsibility for the diving stand.

No formal training is presently provided except for the normal ship qualification program. In view of the criticality of the position in combating casualties and emergencies, a program of instruction is considered to be highly desirable.

2. TRAINER UTILIZATION

Ship control trainers are not available in sufficient number and location for the adequate training of off duty SSBN crews. There are none available for SSN crews. The loading on SSBN trainers in Charleston and New London is now so heavy - and still growing - that each facility needs at least one additional FBM trainer. At present, there are no FBM trainers on the West Coast. An FBM trainer should be supplied for the Mare Island facility since many SSBN's will be overhauled there.

Attack class SSN submarines need realistic team training. The existing facilities at Pearl Harbor, Charleston, New London, and Mare Island cannot effectively perform this function. The SSN's at San Diego have no shore based facility. Norfolk and Key West will have a need for SSN trainers in the future.

The need for additional training is illustrated by the discrepancy noted between the crew's estimate of their capability and observed performance on the trainers. Of significance are typical crew reaction times noted for plane casualties on SSBN trainers. The submarine safety center (SUBSAFECEN) has developed criteria for stern plane recovery action time. Planesmen should note and utilize these criteria for self evaluation since in many cases their performance was not as it should be. It is estimated that many diving stand teams need to reduce their reaction time by an order of magnitude.

Present ship control trainers and practices do not provide for training of OOD's as a team member. This is not a satisfactory approach. The OOD makes the crucial decisions and is responsible for issuing vital orders in recovering from major ship control casualties. In general emergencies, he must factor into his decisions such matters as the tactical situation, navigation factors, speed, depth, and patrol objectives. Not only should the OOD receive training but he should receive that training in the proper team context. The context should include interaction with the DO and division of responsibilities.

Based on observations of ship control trainers in operation at different centers, there is a need to provide both a skilled trainer operator and an instructor with skill and qualifications in nuclear submarines. The dual task loading can be performed by one person at the cost of sacrificing the quality of instruction.

The scope of problems dealt with in trainers today emphasizes flooding and control surfaces. This is as it should be since these are the most critical. However, the most frequent problems are fire and collision. In both cases, judgments must be made; many times ship control action is an essential part of the recovery procedure. Provisions for training in the preparation for emergency ventilation should be included in team training. This is applicable for deep submergence operation.

3. SHIP CONTROL TRAINING CONSIDERATION

One of the main problems in the current operating procedures of personnel controlling the planes is that the scanning pattern is inconsistent with the instrument arrangement. The CIP is in the central field of vision at each station. Yet the instruments on this part of the diving stand are not usually monitored. Instead the backup and supplemental indications on the periphery of the visual field, presumed to have been provided for use by the DO and OOD, are used as the principal information sources. Many ship control personnel do not understand the CIP instruments. Personnel give several reasons for not using the CIP: for example, the CIP indicators are small and hard to read; are not sufficiently sensitive to provide trend; and are less reliable than the peripheral instruments. In addition, the remark was made that, since planesmen are periodically evaluated to determine whether they are cross-checking the peripheral indicators, their best practice is to monitor and use these instruments. The criticism about reliability is questionable since the sensors and power are the same as for many of the peripheral instruments.

The CIP instruments generally provide the components of information for maintaining depth and attitude. Exceptions are indications of plane angles and speed. Lack of integration of the information components is a justifiable complaint. However, it seems that if planesmen were to learn the correct use of the CIP, their task would become more simple and would be performed better.

The relationship between the DO and planesmen is a subject for concern in training. One potential problem is that, while the DO may depend on the planesman for the detection of ship control problems or planes/rudder failure, not all planesmen feel it is their responsibility to so inform the DO. Another problem area is inconsistency in the type of depth change orders that are given. Some DO's will give the new depth only. Others will specify plane

angles. Still others will specify the bubble (ship angle) and depth change.

Standardization of format in depth change orders is considered important for training. Since the members of the teams vary from watch to watch, differences in procedure will result in negative transfer of training gained in on-the-job experience. The alternatives are either to train helmsmen/planesmen in the variety of procedures employed or to have a standard procedure followed by all DO's. Points in favor of explicit and detailed orders are:

1. One of the difficulties faced by a helmsman and stern planesman is to learn to coordinate their actions. For example, it is desirable for the stern planesmen to allow an angle on the ship or maintain a given trim angle, depending on the ship's philosophy, when the fairwater planesman is attempting to change depth.

2. Safe operation of the ship, particularly at high speed, requires that plane angles and motion be minimized. The DO can assist in setting realistic tolerances on the depth to be maintained and safe limits on the plane utilized.

In the near future, ships will be equipped with the Conolog display. However, many existing ships will continue to have the CIP's for a considerable time. The implications for generalized training are somewhat obvious. All trainees must learn the principles of operation of both displays and if practicable should receive practice using both the Conolog and the CIP displays. If the latter is not practicable, then it would seem desirable to provide practice on the CIP. The CIP is more difficult to use. Transfer of training research indicates that if a trainer display cannot be made the same as the operational equipment, it is desirable for students to transfer from the more difficult display in training to the easier one in operation. Solving the problem of differences in displays by using the more difficult display panel is not an optimum solution, although it may be adopted as an economy measure in basic submarine school trainers. If this approach is adopted, personnel assigned as planesmen on ships with Conolog should receive thorough basic training ashore in the principles of operation of the displays and its modes of failure.

Ship acceptance cannot be expected unless hardware capability is understood and means for dealing with improper operation are well in hand.

4. GENERAL EMERGENCY CONSIDERATIONS

The general emergency casualties, including fire, atmospheric

contamination, and flooding, have been analyzed and discussed from the standpoint of casualty control training in the previous sections of this report. Personnel of the submarine forces afloat and shore based facilities have indicated, during interviews, a need for extending the general emergency casualty control training into areas of general emergency damage control training. This training, to be provided on board submarines and at shore based facilities, should be implemented as soon as possible on the basis of a sound damage control training study. Such a study would systematically provide specific damage control training requirements, which would in turn provide a firm basis for determining training-environment requirements and alternate training approaches.

An area requiring special consideration is flooding. The problem faced by personnel has been given serious study by both the Submarine School, and the SUBSAFCEN at New London. There are several related problems associated with the control of flooding casualties. One fundamental area of concern is the nature of presentation of recoverability data. These data show the effects of all-or-none recovery actions from catastrophic flooding. It does not provide a sound basis for discrimination and judgment in fitting the degree of recovery action to the degree of flooding and the ship's speed and depth.

If the water influx is greater than a 1/2-in., 1-in., or 2-in. hole, or if the influx is greater than the drain pump can handle (depending on the criteria of individual ships), it is noted by a local watchstander. The word flooding is passed on an MC system and the OOD's will, on many ships, order "emergency blow," "full rise on the planes," "ahead two-thirds," and "sound the collision alarm." Presumably in this event, the ship's depth, risk of collision or tactical situation might be ignored. This is a verbalized philosophy that follows logically from recovery data and published guidelines. It does not represent a consensus of command and ship philosophy or a desirable approach from the investigators' standpoint.

There are a wide variety of flooding classifications and definitions among ships. Some ships have leakage, flooding, and major flooding with the implication that, based on the watchstander's initial report, "emergency blow" will be immediately ordered only in the case of major flooding. A majority of ships make the distinction strictly on a leakage-versus-flooding basis. Some ships distinguish between criticality of flooding on the basis of depth and some have stated a philosophy of determining the criticality by waiting up to a minute for amplifying reports by watchstanders and an evaluation of ship movements. The definitions cite hull opening sizes or drain pump capacity as guidelines for flooding identification/classification. As an additional guideline, when an objective determination cannot be made, the water influx will be classed as flooding.

The sensible features of flooding are not well known. Few officers and personnel have experienced flooding. Most have to depend on general descriptions. Generally, personnel are instructed to err on the side of caution. Yet blowing to the surface has its dangers too - collision and departing from undetected submerged running. Research to determine flooding manifestations is one area of need.

Exposure of crews to the effects of flooding is generally considered to be one of the most important facets of damage control training; this includes both getting wet and observing hazardous manifestations from a safe vantage point. Since correct behavior patterns under this type of stress are not easily developed, an analytical study of both objectives and methods is necessary to develop an appropriate means of training. A flooding demonstrator similar to the "buttercup" damage control trainer is suggested as a means to provide trainee practice. While safe and under limited stress, the trainee could receive practice in isolation techniques or damage control repair while overcoming his initial fear of getting wet. The complexity of such a training device may vary from a fundamental generalized flooding training compartment to a full-scale duplication of actual ships compartments. Damage control training could also be provided in auxiliary and main sea water systems, hydraulic, drain, ventilation, communication, electrical, and steam systems, and perhaps fire fighting. In any event, both "get wet" type devices (those involving actual exposure while working under safe limits of water pressure and also involving outside-in demonstrations) should be considered. The alternative possibility of using films should not be overlooked for refresher training or even basic training instead of a live outside-in flooding demonstrator, because of both developmental and maintenance expense. An evaluation of the use of a film as an alternative should be part of the recommended damage control study.

5. OTHER SHIP PRACTICES

Currently, it appears possible to develop a limited concept of ship operations; e. g., depth and speed. Thinking and planning for casualties and emergencies in terms of current limits, imposed for safety reasons, may lead to restricted judgment ability when the occasion arises for an immediate reaction to an emergency while running deep at high speed. There is danger here that corrective actions, judgments, and timing may become relaxed, and readiness to respond to casualties at test depths and realistic tactical situations may be limited.

Ships directing their own training have a natural tendency to emphasize, in drills and trainer exercises, casualties of the same nature as experienced by senior officers and personnel. It is important that crews receive training in reacting to the critical and unusual casualties and as many different failures and failure modes as are feasible, not just the common ones.

SECTION V
DISCUSSION

Subsection Three

Ballast Control Panel Trainer, Isolation Training, Communications Trainers, Diving Officer's Training Course

1. BALLAST CONTROL PANEL TRAINER

Effective recovery from many casualties requires a skilled BCPO. He must be capable of reacting to normal operational commands including lineups for normal evolutions and emergency procedures, as well as diagnosis of many possible system malfunctions. He must have the ability to quickly isolate causes of failures in all systems monitored and controlled at the BCP. He must be proficient in operating MBT vent and blow valves (normal and emergency), control of hatch opening, and operation of the trim and drain system, particularly during a flooding casualty. He must also act as a chief communicator with local watchstanders during the isolation phase of casualty recovery. His knowledge of electrical, hydraulic, and pneumatic systems as they relate to BCP operations must be as complete as possible.

Both SSN and SSBN personnel recognize the importance of a well-trained BCPO. A submariner coming aboard a nuclear submarine spends one to four months in general ships qualification. To become BCP qualified requires an additional two to six months. A qualified submariner coming aboard an SSBN will usually be ship qualified in one patrol cycle and BCP qualified in one or more patrol cycles. In either case, considerable training time is expended on the BCPO.

The fact that there is a need for this training is indicated in the presentation of the numerous training requirements for the BCPO (see Table I, Section IV, Subsection Three). Training device requirements are identified in the training methods, Section IV, Subsection Four. An additional demand is often placed on the BCPO's skills and knowledge when he is required as COW to act as backup for the DOOW.

The training of a highly skilled and knowledgable BCPO requires considerable training time. A means of accelerating his training and evaluating his knowledge in a shore based facility is important. The implementation of a BCP emergency procedures trainer would provide the required trainer capability.

The BCP trainer would be an uncomplicated, inexpensive device designed to teach basic operating procedures, as well as an understanding of associated system functions to a semiskilled individual. It would consist of a BCP board with all its switches, meters, and

indicators. The effect of the operator's action on the various systems would be visually displayed in animated schematic form. Malfunction of components or systems would be included as a means of student casualty training and evaluation.

Such a device would make it possible for auxiliary men and IC electricians (or other personnel with previous system knowledge and experience) to learn control and monitoring of systems with which they have not previously had specific detailed experience. A BCP trainer would be inexpensive to build, maintain, and operate. The cost effectiveness of such a device should be favorable since a BCP trainer would provide solid basic training in its own right and also free the more expensive high-fidelity dynamic ship control trainer for advanced training. Significant differences in BCP control-display arrangements between the SSN class and SSBN class ships warrant the development of a BCP trainer for each type of ship.

2. ISOLATION TRAINING (FOR ALL HANDS)

The newer, more complicated submarine requires considerable qualification time before a man is knowledgeable enough to perform effective casualty isolation (electrical, hydraulic, air, steam, oxygen, and water). Early in a given patrol, when there may be many new men aboard ship, there exists an increased danger to the ship's safety. Isolation training is considered highly desirable as an aid in qualifying new men and providing refresher training for qualified men. In particular, isolation training is needed to develop essential knowledges and skills for casualty control.

Apart from the component identification, location, and function for the OOD, DO, BCPO, and maneuvering room watchstanders, isolation training should provide an overall look at alternate methods and modes of system operation. Also all hands should obtain sufficient system knowledge in effects to avoid actions on components during maintenance that could lead to casualties. With a firm grasp of these principles, a man would be readily trained on his ship to perform more rapid casualty identification, avoid errors leading to casualties, thereby limit damage, and possibly prevent loss of ship's control or the capability to cope with emergencies.

For purposes of this study, the electrical, hydraulic and air systems are considered the chief areas where more system training aids and isolation training aids are needed for classroom training.

The major problems in developing generalized shore-training approaches to controlling casualties in these systems lie in the differences between ships. Electric, hydraulic, and air systems differ from ship to ship, class to class, and even in methods of operation on ships where similarities do exist. Because of these detailed differences, a damage control study is needed to identify

common modes of specific failures and problem solutions. Such a study should be combined with a more inclusive damage control training device requirements study, including as a consideration training films for teaching isolation principles and techniques applicable to ship's systems.

A form of isolation training aid considered but rejected during the present study was system schematic display boards. The display panel was deemed feasible for presenting overall system layout and function. But at the detailed system level, where isolation is necessary, enough complexity could not be presented effectively.

3. COMMUNICATIONS TRAINERS

The training requirements for all casualties considered within the study scope have indicated a consistent need for more and better communication training. This training should combine effective classroom training in procedures, phraseology, and flow with practice on a procedural training device. This device is recommended for training both enlisted men and officers at submarine school and submarine shore bases. The communication trainer would be a facility for training a number of (ten to twenty) men to interact simultaneously in correct phraseology and information transmittal. Also included would be the sound effects of all alarms, AN/WIC communication circuits, and sound powered phone circuits. Included in the training would be the priority of MC circuits, alarm recognition, and usage of sound power phones (headset and hand set) under normal conditions and with realistic background noise interjected. Communications practice with emergency breathing apparatus in place is considered an important training aspect of this device. Physically the device will include trainee cubicles with sound dampening to prevent one trainee from receiving direct voice transmission from an adjacent cubicle.

4. DIVING OFFICERS TRAINING COURSE

As submarines increase in capability and complexity, the task load of the DO also increases. At present, many ships employ senior PO's as DOOW's. Since the importance of the DOOW in casualty control cannot be overemphasized, it is extremely important that he be proficient at his task.

Enlisted men serving as DOOW's have had considerable experience and technical competence in the ship's systems. They are usually qualified BCPO's. One major problem confronting them is the lack of understanding of the principles involved in submarine operation that commissioned line officers receive during basic subschool. It is difficult for most personnel to find sufficient time and documentation, without the benefit of formal training, to study, understand, and appreciate the principles, problems, and solutions of trim

analysis and control, compensation, the equilibrium polygon, and casualty effects and control.

The officer who returns to a ship after prolonged shore duty and reports to a markedly different type of ship also finds himself confronted with the problem of self reorientation in these areas.

Common problems for the DOOW are (1) obtaining a real appreciation for the data presented in the recoverability studies as applicable to his ship, (2) understanding bands (speed and depth) of the ship operating envelope, (3) understanding general factors such as tactical situations, and (4) possibly compounding casualties due to personnel errors and malfunctions in systems used for recovery. At the same time, a DOOW must maintain himself free of entanglement in the detailed operation of controls. To reduce the time required to train an enlisted man as DOOW, to increase his effectiveness in casualty control, and to provide refresher training for officers, it is recommended that a short training course for DOOW's be developed. This course would consist of animated films and lectures in the principles, problems, and procedures of ship control, trim analysis and control, compensation, the equilibrium polygon, casualty effects and control, and the application of the data from casualty-recoverability studies.

SECTION V
DISCUSSION

Subsection Four
Feasibility of Generalized Casualty Control Training

1. INTRODUCTION

The feasibility of developing a generalized casualty control trainer(s) has been examined in terms of the tasks to be taught and levels of training required. The results of examining these two factors provided a starting point for determining the fidelity of simulation necessary to ensure that training objectives are fulfilled. Feasibility of generalized training is considered to be parallel and positively related to the degree to which low fidelity of simulation may be tolerated.

In determining the limits of the required training device, the present study breaks down the training levels into three broad categories: (1) basic, (2) intermediate, and (3) advanced. Although a further differentiation has been noted in other sections of this report, the present classification is used in this part of the discussion and treats Levels 2 and 3 in combination. Basic training takes place before personnel are assigned to a specific class of ship, and intermediate/advanced team training occurs after ship assignment. This differentiation was crucial in determining the training device fidelity requirements and the feasibility of generalized casualty control training.

The purpose is to provide as high a degree of positive transfer as possible. The degree of fidelity required to achieve high positive transfer is examined in the subsequent paragraphs of this subsection. This examination is performed for levels of training and the types of behavior function involved in the casualty/task sequences (Appendix C). Behavior functions and variables considered include procedural and tracking tasks, knowledge of results, discrimination and vigilance tasks judgment (decision making), and motion cues.

2. DISCUSSION

The use of simulation for training has many important applications and advantages. Use of the real system under live conditions may be too costly, dangerous, or impractical. Such would be the case for much of the submarine casualty control training. Demonstrations of such casualties as flooding, fire, and ship control failure are certainly too dangerous and impractical for exercise in an operational situation. Furthermore, by using simulation techniques

it is possible to realize more precise control over the training process. Known inputs can readily be manipulated to provide for a particular training objective(s), and more accurate knowledge of results can be obtained.

The question of the required degree of fidelity of simulation is considered with respect to three aspects of simulation and training: (1) the equipment and functions to be simulated, (2) how accurately the stimulus situations on which training is given must simulate real life and (3) the type of training to be accomplished; e.g., levels of training and behavior to be emphasized (procedures, tracking, discriminations, and judgments).

Training equipment requirements for the early stages of learning emphasize knowledge of fundamentals, individual training in rudimentary procedures, and tracking skills with low fidelity control, displays, arrangements, and functions but without simulation of environmental features (Smode, Gruber, and Ely, 1963).

As the levels of learning become more sophisticated, the training equipment must become more complex. There is emphasis on such features as active trainee participation; closed-loop specific system representation; high fidelity requirements in displays, controls and environments; and whole task representation involving integrated equipments.

As previously mentioned the degree of fidelity of simulation requirements will, to a large extent, depend on the type of training to be performed.

The assumption behind the use of simulators is that transfer from the training situation to the operational situation increases as the two situations become more similar. Therefore, in missions that are complicated and hazardous and that require highly developed skills, it is essential that the transfer from the training environment to the operational environment be perfect or nearly so (Angell, Shearer, and Berlaner, 1964). The risk of low fidelity in advanced stages of complex learning of habit regression under stress (emergency), which would be evidenced by the reappearance of older inappropriate responses, was pointed out by Smode, Gruber, and Ely (1963). This is a major risk in using low fidelity trainers for emergency training. With high fidelity of simulation, learning rate on a trainer does not significantly differ from that gained in equal time on an aircraft (Dougherty, Houston, and Nickias, 1957). Kause (1960) states that where operational flight tasks require perfect execution on the first trial without the opportunity for inflight training (e.g., emergency procedures), simulation must provide for complete transfer of training. The pre ding citations justify the requirement of avoiding any possible deviation in behavior during advanced training from that expected aboard ship in an emergency. Since the present study is concerned with casualty emergency (or

first-of-a kind situation) the need for high fidelity does exist, at least in advanced training.

In discussing the specific training requirements involved in the area of ship casualty control, the elements of behavior fall into three broad categories: (1) motor, (2) discrimination, and (3) judgment. Motor responses (actions) can further be divided into procedural (motor) emergency tasks, which will vary in effectiveness depending on the level of training. In basic procedural training, a generalized trainer is the only practical solution. Since the physical arrangement of displays and controls differs considerably from one class of submarines to the next, any trainer must be of a generalized nature. It is not known at the time of basic training what class of ship (submarine) personnel will be assigned. Therefore, generalized training in or relevant to emergency procedures is the only feasible solution for acquisition of basic casualty emergency training. Since a generalized trainer will, by definition, have a limited fidelity relative to ships, the possibility of negative transfer of training arises. However, it should be pointed out that considerable knowledge and nonship specific skills can be taught in a generalized ship control trainer. Some negative transfer of training will result. But since only rudimentary levels of procedural skills will be acquired at basic subschool in the limited time available, a serious problem will not arise.

Numerous studies, as described by Adams, Garrett, and Robertson (1961), indicate that for many simple (uncombined) psychomotor activities, high positive transfer occurs with limited fidelity of simulation. Since the objective here is to teach basic procedural skills for normal operation, as opposed to the complex of activities to be performed under stress in controlling an emergency aboard a specific ship, use of a generalized casualty control trainer appears feasible for basic procedures.

In contrast to the basic training philosophy, intermediate and advanced training must be specific to the type of equipment and the class of ship to which personnel are assigned. Personnel will receive both the intermediate and advanced procedure training after being assigned to a specific class of submarine. During these phases of training, personnel will learn specific procedural tasks that they may be required to perform during an emergency. In an emergency situation, it is imperative that certain procedural sequences be accomplished in a minimum of time with extreme accuracy. Therefore, it is necessary to train individuals until such actions become essentially automatic. The high fidelity dynamic ship control simulator is especially appropriate for such training (Parker and Downs, 1961). As a result of this stage of training, personnel should develop the ability to respond to a signal without having to think out what to do. Some degree of automatization is vitally necessary in order that a number of activities may be performed at the same time. As Miller (1960) has noted: "Unlike instructed response or familiarization training the automation of performance should be made in a

practice situation that closely simulates ship casualty situations."

As further evidence on the need for high fidelity in training for emergency procedures, Newton (1959) investigated the effectiveness of the training of procedural tasks (depth and course changes) with different levels of simulation. The findings indicated that on a proficiency test averages were ranked in a positive relationship with simulator complexity. Lack of fidelity (such as motion) consistently resulted in the poorest performance on the proficiency test. This finding is relevant in view of Miller's (1960) observations and those cited by Smode, Gruber, and Ely (1963). These kinds of results show the importance of high fidelity of simulation in intermediate/advanced casualty procedural training. The lives of fellow crew members and the safety of the ship may well depend on the precise automatic performance of such procedural tasks in view of the very short reaction times crucial for ship recovery from critical casualties.

It is in the area of advanced training where the importance of team training is realized. The importance of high fidelity training for team interaction was studied by Briggs and Naylor (1964). They found that for tasks requiring interaction between radar controllers (RC's), high fidelity simulation (training) resulted in significantly better performance. In a second experiment, Naylor and Briggs (1965) found transfer performance was highest for the high-task complexity and low organization. In light of the previously cited evidence and arguments on similarity of training and operational tasks regarding transfer, it seems reasonable to conclude that high fidelity of simulation is required to achieve high team performance on complex procedures. Naylor and Briggs also stress the importance of advanced individual skills in team tasks.

In his discussion on task and part task trainers, Miller (1960) indicates that procedural trainers may run the gamut from "familiarization trainers to automatic skill trainers." He states that the type of training to be accomplished (basic or advanced) might well determine the type to be used and the amount of fidelity required by each.

As mentioned previously (Section IV, Subsection Four), results indicate familiarization trainers (demonstrators and nomenclature/-location trainers) or some adaptation will be useful as basic casualty trainers, whereas for advanced emergency training a high fidelity dynamic ship control trainer will be required. The latter is especially true for emergency training wherein time to think out the action is virtually nonexistent. The members of the ship control party (and sometimes local watchstanders) in some general emergencies must immediately act correctly and automatically.

Training for tracking tasks, like that for procedural tasks, must be considered with respect to basic and intermediate/advanced training.

The reasons for utilizing a generalized trainer for basic tracking training are the same as those for basic procedural training, although in this discussion the consideration of knowledge of results (feedback) is especially important and will be covered at this time.

The basic trainer used for early tracking training must exhibit the dynamic characteristics of the tracking equipment. Even though high fidelity of display, control feel, or control/display relations may not be required for basic training, dynamic simulation is required to provide the trainee with performance feedback (knowledge of results).

Knowledge of results (KR) provides trainees with information on how well they are doing and whether their responses are correct. Laboratory studies consistently report either that KR is essential for learning to take place or at least that KR produces more learning or more rapid learning than performance without feedback (Biel, 1962). According to Adams, Garrett, and Robertson (1961): "Results show that whenever crew judgment and action are based on precise values, great care should be exercised in accurately simulating relevant variable." A number of normal and emergency procedures are covered by this conclusion because all members of the ship control party must respond to small instrument deviations. A large number of laboratory studies summarized by Adams, Garrett, and Robertson (1961) show that, in training for normal tracking tasks, fidelity is not important in target characteristics, proprioceptive feedback, or control display relationships.

Regarding the specificity of feedback required for learning, Naylor, Briggs, and Buckhout (1963) performed an experiment to determine the effects of various conditions of auditory performance feedback on a continuous tracking and procedural task. They found that transfer performance is significantly related to feedback specificity during training.

In addition, Cotterman (1960) investigated the effects of variation on the specificity of KR to the improvement of a perceptual skill. He concluded that KR increases the rate and level of learning to perform an absolute judgment of spatial extent and that this effect is generally greater with greater specificity (or faithfulness) of the knowledge of results.

Numerous uncited studies on the effects of KR on training also support the contention that a dynamic simulator is required for training in tracking (depth changing, etc.).

The research cited above indicated that the more specific the feedback, the more effective the training. The implication for intermediate and advanced training is that the ship control parties should be trained on simulators specific to the class of ship (submarine) to which they are assigned. Since precise action is required, as in an

emergency situation, a high fidelity simulator is required for advanced automatized skill training. The fidelity of such factors as control-display and feel relationships, control resistance, control action, control limits, KR, and control interaction must be high to assure high transfer of training to operational emergency situations.

Discrimination tasks must be considered when determining the fidelity requirements for training in ship casualty control. Discrimination tasks are those of scanning and vigilance from the ship control standpoint. Scanning is involved in the checking for and detection of abnormal indications and conditions. Training in this activity is required to develop the most effective scan pattern for the detection of emergency conditions particularly since (as described in Section IV, Subsection One) diving panel layout and personnel practice may be incompatible. Discrimination tasks also deal with response to alarms, both visual and auditory. It is also concerned with control-display feel rates, effective communication, and the performance of followup checks.

In the case of basic discrimination training, much of the previously discussed information applies. The case for the feasibility of basic generalized casualty control training still applies, but because of the critical actions in scanning the ship control indicators and exacting casualty detection and identification time requirements, a high-fidelity trainer is required for advanced training.

For the basic training situation, development of an effective scan pattern might be aided by a static display system as long as the physical representation is of reasonable fidelity. Where control-display/feel rates are involved in emergency situations (overlap with tracking), dynamic simulation is essential to provide the trainee with performance feedbacks.

In their study on visual time-sharing Gabriel, Burrows, and Abbott (1965) reference the research efforts of others who found that less than full simulation is valuable in many visual training situations. However, for reasons given previously, a high-fidelity dynamic simulator trainer is needed for the intermediate and advanced training situations. Time is an extremely critical factor, and maximum transfer of training is imperative. The wide variation in physical arrangement of many controls and displays from ship to ship makes a faithful representation of a specific class of ship for the trainee a must.

Since KR vigilance (monitoring and scanning) training is important to positive transfer (Adams and Humes, 1963) a high-fidelity simulator is required for advanced casualty control training. This is particularly true in light of the ship to ship differences and the criticality of time in emergency situations. Transfer from basic search training (because of ship differences) as against individual indicator

interpretation will be minimal. Hence, advanced training should provide a high level of task similarity to that of casualty indications aboard the assigned ship. Knowledge of the ship response provides personnel with important cues to impending abnormal conditions as well as the effectiveness of a maneuver. Without this knowledge, personnel would be forced to take emergency actions without awareness of the effectiveness of such actions. This point argues for high fidelity dynamic simulation in advanced training.

The third and final area to be considered in casualty control training is judgment. It can best be discussed by considering the factors involved in the decision-making process. A casualty control decision is based on such items as long term memory (ship and CO instructions, tactical situation, navigational factors, and crew factors), short term memory (ship status, and ship system status, e.g., propulsion, power and hydraulics), communication, control limits, control interaction, and control-display/feel rates.

Since decision-making (judgment) calls for team interaction (communication and psychomotor responses) and must be based on the vagaries of a particular ship, no basic training over and above the present basic submarine school for officers is considered to be necessary. Training methods under consideration will thus be limited to advanced high fidelity dynamic ship control training.

Teichner and Myers (1961) as a result of several studies dealing with various aspects of human decision making, list the following recommendations about decision-making training:

1. Emphasis should be placed on studies of methods for increasing the short term memory capacity for rapid information processing in the training of naval personnel making either status or action decisions.

2. Training criteria should be developed that are cognizant of the fact that the decision maker can process and apply to the making of decisions more information than he can consciously report at the time.

3. Indoctrination of naval personnel should be geared to full awareness of the value that the Navy places upon the possible results of their decisions. Intelligent decisions cannot be made unless the decision maker knows what gains and losses are associated with his alternatives.

4. It should be emphasized in training decision-making personnel that their estimates of the relative frequency and average payoffs associated with various events are reliable and, hence, should be utilized.

5. In situations involving continued monitoring of a display, the operator may be required to make the same

choice numerous times. High motivation and full awareness by the operator of the importance of his position and the decisions that he makes should deter him from deviating from optimal strategies. This is crucial to casualty prevention and early detection.

6. Training procedures should consider and attempt to eliminate or minimize certain response tendencies of decision makers. Gains and losses associated with choices open to the decision maker tend to have influences. Thus, the individual may avoid an alternative because it could result in some loss, even though the probability of the loss is slight. There is a less marked tendency, but a very definite one, to choose strategies that could result in larger payoffs, but in actuality rarely do.

7. Another response tendency that should be guarded against during training is that of paying undue attention to the results of immediately preceding decisions in situations where these events are essentially independent. The individual's assessment of the relative frequencies of events displayed is probably unchanged by his experience in making decisions, but his estimate of what will happen the very next time is. This suggests that naval personnel should be trained and indoctrinated to act in terms of the long term probabilities of displayed events rather than their own momentary "hunches" about what will happen next. These recommendations are applicable to the present training situation. A method for increasing short term memory capacity would be of great value in the decision-making process, since the decision will be influenced by such factors as ship status (depth, speed, and angle), ship system status, crew status, tactical situation, navigational factors, patrol objectives, and many others. At least some of these items are continually changing and therefore are short-term memory items. The ability and desire to remain undetected and the risk of collision by compounded casualties, which might happen in broaching or excessive angles or roll, is a primary concern in any decision-making situation. Indoctrination must ensure that personnel are always aware of such possibilities and consequences as are involved in deciding upon alternative actions. It is also evident that previous experience on ships is a valuable aid to decision making in times of crisis. Personnel must maintain awareness of past experience and their application to the present situation. They must recall and be able to profit from

such factors as previous experience, including team action and cooperation under similar stressful situations. Personnel must also be trained to rely on proven strategies or routines and avoid playing hunches or taking unnecessary risks.

The preceding objectives can be achieved in Basic Sub School and updated in wardroom discussions, given proper aids. However, achieving a complete decision-making capability requires a high-fidelity ship control team trainer in addition to exercise in all crew positions on a basic generalized ship control trainer and exercise during the basic ship tour. Miller (1960) discusses the propensities required in a problem-solving or decision-making trainer. He states that "decision-making characteristically requires the recall of stored data (which often is presented in the form of a number of variables) and the selection of a mode of response according to some anticipation of the likely consequences of the response." He also states that symbolic inputs and outputs are sufficient for such training unless the decision is time stressed; and that operational feedback is not required unless a series of decisions is based on control settings. Miller recommends a simple (low-fidelity) decision-making trainer for nonstressful situations. However, the decision-making task of the DO and OOD in major casualties is not limited to the scope of the quoted decision-making process:

1. The officer not only has many indications on the BCP and diving stand, but they are distant and hard to read.

2. He is subject to numerous alarms.

3. Frequently the situational variables, such as the tactical situation, are not accurately known.

4. The officer's input channels of information include subjective voice reports and status indications from other compartments.

5. His alternate modes of action need to be programmed on the basis of numerous situational variables including depth bands, initial speed, etc.

6. He must attend to feedback indications, gage his initial orders, and take followup action so as to reach a safe operating envelope.

7. He must exercise judgment and be sensitive to ship accelerations (feel of ship motion and attitude).

In conclusion, the requirements for training in decision-making must progress through early stages of part task training in the classroom and generalized dynamic trainers and then to simplified whole training, culminating in shipboard drills and practice aboard a high-fidelity team simulator trainer.

Motion simulation, the last item for discussion on the topic of generalized casualty control training, serves as a cue for normal-abnormal operation as feedback and as a noise and hazard factor.

Reference is made to Buckhout, et. al., (1963) as evidence of the contribution of fidelity of motion simulation to positive transfer of training. These authors state that "this motion provides an additional information input to the pilot and, therefore, quite likely facilitates performance." They also indicate that, where reasonably precise maneuvering is required, such as in fire control or terrain contour flying, performance with simulated motion conditions more closely resembles flight performance than does static simulator performance.

Finally, the positive relationship of command and control to fidelity of motion is a requirement not only as a decision-making cue but as feedback for the control actions. In submarine simulation Newton (1959) has demonstrated effectiveness of motion in a series of submarine maneuvers including both course and depth changes.

As a concluding comment to this discussion the Navy (Aviation Daily, 1963) has reported what has been called a "new twist" for flight simulators - "kinetic cueing." It consists of adding an action picture of flight operation to the motion of the simulator. A significant increase in the number of successful approaches and touchdowns has occurred since the addition of this extra (kinetic) cue. Superior performance was also shown by the kinetically trained crew in simulated emergencies. Data such as this show the need for high fidelity of motion cues or the learning of motor responses.

SECTION VI
CONCLUSIONS

Throughout Section V, generalized basic casualty control training has been evaluated in terms of fidelity of simulation required, with an emphasis on ship control as defined in earlier sections of the report. The philosophy has been that a generalized ship control trainer plus classroom aids, a flooding demonstrator, communication procedures training, and BCP emergency procedures trainers offer a practical solution to basic casualty control training. This approach is based on the premise that more specific training is impractical and unnecessary until the personnel are assigned to a particular class of submarines, at which time they will receive intermediate and advanced training to peak out individual and team skills on a high-fidelity dynamic ship control trainer. Some of the earlier devices mentioned should also be used in intermediate transition and advanced team levels of training.

The specific features required in the generalized trainer(s) may depend on the particular skill to be learned. For example, classroom aids (previously mentioned) or other presented material can be utilized for generalized training of the fundamental principles or rudimentary procedures of emergency casualty control. Such aids, mockups, or actual equipment can also be of value in the training of component characteristics and system effects and basic communication procedures.

In addition, the skills developed in procedural trainers, isolation/damage control trainers, and flooding demonstration trainers are likely to be generalizable to the operational situation.

Skills and information derived from such trainers can be expected to be generalizable and exhibit positive transfer (in varying degrees) to casualty control situations aboard specific classes of ships.

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4. DATA COLLECTION VISITATIONS

a. Facilities

Charleston, S. C.

Fleet Ballistic Missile Training Center

Commander, Submarine Flotilla Six

APPENDIX A

Norfolk, Va.

Commander, Submarine Force, U.S. Atlantic Fleet

New London Area, Conn.

Deputy Commander, Submarine Force, U.S. Atlantic Fleet

Officer In Charge, U.S. Naval Submarine School

Commander, Submarine Development, Group Two

Submarine Safety Center

Pearl Harbor, Hawaii

Commander, Submarine Force, U.S. Pacific Fleet

Commander, Submarine Division Seventy-one

Commander, Submarine Division Seventy-two

Chief of Staff, Submarine Squadron Fifteen Representative

Commander, Fleet Submarine Training Facility

Washington, D.C.

Bureau of Naval Personnel

Bureau of Ships

Bureau of Weapons, Special Projects Office

Office of the Chief of Naval Operations

b. Ships

USS Barb, (SSN 596)

USS Nathaniel Greene, (SSBN 636), Gold

USS Shark, (SSN 591)

USS Von Steuben, (SSBN 632), Blue

c. Off Duty SSBN Officers

USS Daniel Boone, (SSBN 629), Gold

USS John C. Calhoun, (SSBN 630), Gold

USS Ulysses S. Grant, (SSBN 631), Blue

USS Stonewall Jackson, (SSBN 634), Gold

USS Lafayette, (SSBN 616), Blue

USS James Madison, (SSBN 627), Blue

USS Sam Rayburn, (SSBN 635), Blue

USS Tecumseh, (SSBN 628), Blue

USS Woodrow Wilson, (SSBN 624), Blue

APPENDIX B
CASUALTY IDENTIFICATION AND CLASSIFICATION

CLASS I - SHIP COMMAND AND CONTROL

Subclass A - Stern Plane Casualties

Sub-subclass 1. Fail on full dive

- a. Actual failure - mechanically jammed
- b. Instrument failure
- c. Hydraulic plant failure
  - (1) Lose "normal" mode
  - (2) Lose "emergency" mode
  - (3) Lose (1) and (2)
  - (4) Lose all hydraulics[a]
- d. Electrical system failure
- e. Improper operator setting

Sub-subclass 2. Fail on full rise

- a. Actual failure - mechanically jammed
- b. Instrument failure
- c. Hydraulic plant failure
  - (1) Lose "normal" mode
  - (2) Lose "emergency" mode
  - (3) Lose (1) and (2) above
  - (4) Lose "manual" mode
  - (5) Lose all hydraulics[a]
- d. Electrical system failure
- e. Improper operator setting

Sub-subclass 3. Fail at ≥ 0 deg ≤ 20 deg dive

- a. Actual failure - mechanically jammed
- b. Instrument failure
- c. Hydraulic plant failure
  - (1) Lose "normal" mode

---

[a]To include pipe rupture, servovalve failure, transfer valve failure, normal amplifier failure, standby amplifier failure, 400-cps power loss, AMC computer, or system failure.

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(2) Lose "emergency" mode
(3) Lose (1) and (2) above
(4) Lose "manual" mode
(5) Lose all hydraulics[a]

d. Electrical system failure
e. Improper operator setting

Sub-subclass 4. Fail at ≥0 deg ≤20 deg Rise

a. Actual failure - mechanically jammed
b. Instrument failure
c. Hydraulic plant failure
(1) Lose "normal" mode
(2) Lose "emergency" mode
(3) Lose (1) and (2) above
(4) Lose "manual" mode
(5) Lose all hydraulics[a]

d. Electrical system failure
e. Improper operator setting

Subclass B - Bow/Fairwater Plane Casualties

Sub-subclass 1. Fail on full dive

a. Actual failure - mechanically jammed
b. Instrument failure
c. Hydraulic plant failure
(1) Lose "normal" mode
(2) Lose "emergency" mode
(3) Lose (1) and (2) above
(4) Lose "manual" mode
(5) Lose all hydraulics[a]

d. Electrical system failure
e. Improper operator setting

[a]To include pipe rupture, servovalve failure, transfer valve failure, normal amplifier failure, standby amplifier failure, 400-cps power loss, AMC computer, or system failure.

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Sub-subclass 2. Fail on full rise

a. Actual failure - mechanically jammed

b. Instrument failure

c. Hydraulic plant failure

(1) Lose "normal" mode

(2) Lose "emergency" mode

(3) Lose (1) and (2) above

(4) Lose "manual" mode

(5) Lose all hydraulics[a]

d. Electrical system failure

e. Improper operator setting

Sub-subclass 3. Fail at ≥ 0 deg ≤ 20 deg dive

a. Actual failure - mechanically jammed

b. Instrument failure

c. Hydraulic plant failure

(1) Lose "normal" mode

(2) Lose "emergency" mode

(3) Lose (1) and (2) above

(4) Lose "manual" mode

(5) Lose all hydraulics[a]

d. Electrical system failure

e. Improper operator setting

Sub-subclass 4. Fail at ≥ 0 deg ≤ 20 deg dive

a. Actual failure - mechanically jammed

b. Instrument failure

c. Hydraulic plant failure

(1) Lose "normal" mode

(2) Lose "emergency" mode

(3) Lose (1) and (2) above

(4) Lose "manual" mode

(5) Lose all hydraulics[a]

---

[a]To include pipe rupture, servovalve failure, transfer valve failure, normal amplifier failure, standby amplifier failure, 400-cps power loss, AMC computer, or system failure.

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d. Electrical system failure

e. Improper operator setting

Subclass C - Steering Casualties

Sub-subclass 1. Rudder fails at "hard right/left"

a. Actual failure - mechanically jammed

b. Instrument failure

c. Hydraulic plant failure

(1) Lose "normal" mode

(2) Lose "emergency" mode

(3) Lose (1) and (2) above

(4) Lose "manual" mode

(5) Lose all hydraulics[a]

d. Electrical system failure

e. Improper operator setting

Sub-subclass 2. Rudder fails at ≥ 0 deg ≤ 35 deg R/L

a. Actual failure - mechanically jammed

b. Instrument failure

c. Hydraulic plant failure

(1) Lose "normal" mode

(2) Lose "emergency" mode

(3) Lose (1) and (2) above

(4) Lose "manual" mode

(5) Lose all hydraulics[a]

d. Electrical system failure

e. Improper operator setting

Subclass D - Main Ballast Tank Blow Systems

Sub-subclass 1. Forward group won't blow

a. Switch failure

b. Solenoid failure

c. Valve failure

---

[a]To include pipe rupture, servovalve failure, transfer valve failure, normal amplifier failure, standby amplifier failure, 400-cps power loss, AMC computer, or system failure.

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d. Piping failure
e. Flask failure
f. Improper control setting
g. Instrument error/failure

Sub-subclass 2. After group won't blow
a. Switch failure
b. Solenoid failure
c. Valve failure
d. Piping failure
e. Flask failure
f. Improper control setting
g. Instrument error/failure

Sub-subclass 3. No. 1 MBT won't blow
a. Switch failure
b. Solenoid failure
c. Valve failure
d. Piping failure
e. Flask failure
f. Improper control setting
g. Instrument error/failure

Sub-subclass 4. Low pressure blower won't blow
a. Mechanical failure of blower
b. Switch failure
c. Valve failure
d. Piping failure
e. Pressure regulator failure
f. Improper control setting
g. Instrument error/failure

Sub-subclass 5. Diesel engine won't blow
a. Mechanical failure of engine
b. Starting air failure
c. Valve failure
d. Piping failure
e. Improper control setting

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Sub-subclass 6. Emergency blow system
- a. Switch failure
- b. Actuating flask bled down
- c. Gas generator or flask failure
- d. Valve failure
- e. Piping failure
- f. Improper control setting
- g. Instrument error/failure

Subclass E - Negative Tank System

Sub-subclass 1. HP blow system failure
- a. Switch failure
- b. Solenoid failure
- c. Blow valve failure
- d. Piping failure
- e. Improper control setting
- f. Indicator error/failure

Sub-subclass 2. 225 PSI blow system failure
- a. Valve failure
- b. Piping failure
- c. Improper control setting
- d. Indicator error/failure

Sub-subclass 3. Flood valve failure
- a. Valve or hydraulic failure
- b. Switch failure
- c. Solenoid failure
- d. Improper control setting
- e. Indicator error/failure

Sub-subclass 4. Vent valve failure
- a. Valve or hydraulic failure
- b. Switch failure
- c. Solenoid failure
- d. Improper control setting
- e. Indicator error/failure

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Sub-subclass 5. Trim system failure

a. Switch failure
b. Solenoid failure
c. Valve failure
d. Piping
e. Improper control setting
f. Indicator error/failure

Subclass F - Main Ballast Tank Vent System Failures

Sub-subclass 1. Vents open

a. Switch failure
b. Solenoid failure
c. Hydraulic system failure
d. Piping failure
e. Valve failure
f. Improper control setting
g. Indicator error/failure

Sub-subclass 2. Vents shut

a. Switch failure
b. Solenoid failure
c. Hydraulic system failure
d. Piping failure
e. Valve failure
f. Improper control setting
g. Indicator error/failure

Subclass G - Variable Ballast System

Sub-subclass 1. Trim pump failure

a. Switch failure
b. Other electrical system (motor, controller, circuit breakers)
c. Mechanical failure (pump and/or suction and discharge valves)
d. Priming pump failure
e. Improper control setting
f. Instrument error/failure

Sub-subclass 2. Forward trim tank failure

- a. Switch failure
- b. Solenoid failure
- c. Valve failure
- d. Piping failure
- e. Improper control setting
- f. Indicator error/failure

Sub-subclass 3. After trim tank failure

- a. Switch failure
- b. Solenoid failure
- c. Valve failure
- d. Piping failure
- e. Improper control setting
- f. Indicator error/failure

Sub-subclass 4. Auxiliary tank(s) failure(s)

- a. Switch failure
- b. Solenoid failure
- c. Valve failure
- d. Piping failure
- e. Improper control setting
- f. Indicator error/failure

Sub-subclass 5. Water round torpedo (WRT) tanks(s) failure(s)

- a. Switch failure
- b. Solenoid failure
- c. Valve failure
- d. Piping failure
- e. Improper control setting
- f. Indicator error/failure
- g. Torpedo tube interlocks broken

Sub-subclass 6. Hovering tank(s) failure(s)

- a. Switch failure
- b. Solenoid failure
- c. Valve failure
- d. Piping failure

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e. Improper control setting

f. Indicator error/failure

Subclass H - Mast System Failures

Sub-subclass 1. ECM mast failure

a. Switch failure

b. Solenoid failure

c. Valve failure

d. Piping failure

e. Mechanical failure (binding - stuck)

f. Improper control setting

g. Indicator error/failure

h. Hydraulic system failure

Sub-subclass 2. Radio antenna mast(s) failure(s)

a. Switch failure

b. Solenoid failure

c. Valve failure

d. Piping failure

e. Mechanical failure (binding - stuck)

f. Improper control setting

g. Indicator error/failure

h. Hydraulic system failure

Sub-subclass 3. Radar mast failure

a. Switch failure

b. Solenoid failure

c. Valve failure

d. Piping failure

e. Mechanical failure (binding - stuck)

f. Improper control setting

g. Indicator error/failure

h. Hydraulic system failure

Sub-subclass 4. Snorkel mast failure

a. Switch failure

b. Solenoid failure

c. Valve failure
d. Piping failure
e. Mechanical failure (binding - stuck)
f. Improper control setting
g. Indicator error/failure
h. Hydraulic system failure

Sub-subclass 5. Periscope(s) failure(s)

a. Switch failure
b. Solenoid failure
c. Valve failure
d. Piping failure
e. Mechanical failure (binding - stuck)
f. Improper control setting
g. Indicator error/failure
h. Hydraulic system failure

Subclass I - Automatic Maneuvering Control (AMC) System Failure

Sub-subclass 1. Depth control failure

a. Switch failure
b. Computer failure (mechanical or electrical)
c. Improper control setting
d. Sensor input error or failure
e. Amplifier failure

Sub-subclass 2. Depth rate failure

a. Switch failure
b. Computer failure (mechanical or electrical)
c. Improper control setting
d. Sensor input error or failure

Sub-subclass 3. Trim control failure

a. Switch failure
b. Computer failure (mechanical or electrical)
c. Improper control setting
d. Sensor input error or failure
e. Amplifier failure

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Sub-subclass 4. Course control failure
- a. Switch failure
- b. Computer failure (mechanical or electrical)
- c. Improper control setting
- d. Sensor input error or failure

Sub-subclass 5. Turn rate failure
- a. Switch failure
- b. Computer failure (mechanical or electrical)
- c. Improper control setting
- d. Sensor input error or failure

Subclass J - Interior Communication Systems Failure

Sub-subclass 1. MC failure
- a. Electrical failure
- b. Improper control setting

Sub-subclass 2. 2 MC failure
- a. Electrical failure
- b. Improper control setting

Sub-subclass 3. 4 MC failure
- a. Electrical failure
- b. Improper control setting

Sub-subclass 4. 7 MC failure
- a. Electrical failure
- b. Improper control setting

Sub-subclass 5. 21 MC/27 MC (integrated announcing systems) failure
- a. Electrical failure
- b. Improper control setting

Sub-subclass 6. 31 MC
- a. Electrical failure
- b. Improper control setting

Sub-subclass 7. 32 MC failure (SSBN's only)
- a. Electrical failure
- b. Improper control setting

Sub-subclass 8. 10 JC failure (SSBN's only)
- a. Electrical failure

b. Improper control setting

Sub-subclass 9. X1J failure

a. Electrical open, ground, or short

b. Faulty hand/head set

c. Improper control setting (isolation or press-to-talk switch)

Sub-subclass 10. X43J failure (SSBN's only)

a. Electrical open, ground, or short

b. Faulty hand/head set

c. Improper control setting (isolation or press-to-talk switch)

Sub-subclass 11. X60J failure

a. Electrical open, ground, or short

b. Faulty hand/head set

c. Improper control setting (isolation or press-to-talk switch)

Sub-subclass 12. JA failure

a. Electrical open, ground, or short

b. Faulty hand/head set

c. Improper control setting (isolation or press-to-talk switch)

CLASS II - GENERAL EMERGENCIES

Subclass A - Fire

Sub-subclass 1. Class A fire (cloth, wood, etc.)

a. Bow compartment (SSN-594 and later attack types only)

b. Torpedo room, forward

c. Torpedo room, midships (SSN-594 and later attack types only)

d. Control room and attack center

e. Other berthing spaces

f. Galley and messing areas

g. Sonar room

h. Radio room

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i. Navigation center (SSBN's only)

j. Missile control center (SSBN's only)

k. Missile compartment (SSBN's only)

l. Air regeneration/CO_2 scrubber room (attack type only)

m. AMR No. 1, (SSBN's only) or air regeneration room (SSN's)

n. AMS/AMR No. 2

o. Maneuvering room

p. Engine room

q. Battery well

r. Diesel engine space

s. Reactor compartment tunnel

t. Reactor compartment, lower level

Sub-subclass 2. Class B fire (oil)

a. Bow compartment (SSN-594 and later attack types only)

b. Torpedo room, forward

c. Torpedo room, midships (SSN-594 and later attack types only)

d. Control room and attack center

e. Other berthing spaces

f. Galley and messing area

g. Sonar room

h. Radio room

i. Navigation center (SSBN's only)

j. Missile control center (SSBN's only)

k. Missile compartment (SSBN's only)

l. Air regeneration/CO_2 scrubber room (attack type only)

m. AMR No. 1, (SSBN's only) or air regeneration room (SSN's)

n. AMS/AMR No. 2

o. Maneuvering room

p. Engine room

q. Battery well

r. Diesel engine space

Sub-subclass 3. Class C fire (electrical)

a. Bow compartment (SSN-594 and later attack types only)

b. Torpedo room, forward

c. Torpedo room, midships (SSN-594 and later attack types only)

d. Control room and attack center

e. Other berthing spaces

f. Galley and messing area

g. Sonar room

h. Radio room

i. Navigation center (SSBN's only)

j. Missile control center (SSBN's only)

k. Missile compartment (SSBN's only)

l. Air regeneration/CO_2 scrubber room (attack type only

m. AMR No. 1, (SSBN's only) or air regeneration room (SSN's)

n. AMS/AMR No. 2

o. Maneuvering room

p. Engine room

q. Battery well

r. Diesel engine space

Subclass B - Flooding

Sub-subclass 1. Bow compartment (SSN-594 and later attack types only)

a. Upper level

(1) Through pressure hull

(2) Between hull stop and back-up stop valves

(3) Downstream of back-up stop valve

b. Lower level

(1) Through pressure hull

(2) Between hull stop and back-up stop valves

(3) Downstream of back-up stop valve

Sub-subclass 2. BQS-6 dome (SSN-594 and later attack types only)

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(1) Through pressure hull

Sub-subclass 3. Torpedo room, forward (all except SSN-594 and later attack types)

a. First platform deck

(1) Through pressure hull

(2) Between hull stop and backup stop valves

(3) Downstream of backup stop valve

b. 2nd platform deck

(1) Through pressure hull

(2) Between hull stop and backup stop valves

(3) Downstream of backup stop valve

c. 3rd platform deck

(1) Through pressure hull

(2) Between hull stop and backup stop valves

(3) Downstream of backup stop valve

Sub-subclass 4. Operations compartment (less battery well)

a. First platform deck

(1) Through pressure hull

(2) Between hull stop and backup stop valves

(3) Downstream of backup stop valve

b. 2nd platform deck

(1) Through pressure hull

(2) Between hull stop and backup stop valve

(3) Downstream of backup stop valve

c. 3rd platform deck

(1) Through pressure hull

(2) Between hull stop and backup stop valve

(3) Downstream of backup stop valve

Sub-subclass 5. Missile compartment

a. First platform deck

(1) Through pressure hull

(2) Between hull stop and backup stop valve

(3) Downstream of backup stop valve

b. 2nd platform deck

(1) Through pressure hull

(2) Between hull stop and backup stop valve
(3) Downstream of backup stop valve

c. 3rd platform deck
(1) Through pressure hull
(2) Between hull stop and backup stop valve
(3) Downstream of backup stop valve

Sub-subclass 6. AMR No. 1 (SSBN's only)

a. Upper level
(1) Through pressure hull
(2) Between hull stop and backup stop valve
(3) Downstream of backup stop valve

b. Lower level
(1) Through pressure hull
(2) Between hull stop and backup stop valve
(3) Downstream of backup stop valve

Sub-subclass 7. AMS/AMR No. 2

a. Upper level
(1) Through pressure hull
(2) Between hull stop and backup stop valve
(3) Downstream of backup stop valve

b. Lower level
(1) Through pressure hull
(2) Between hull stop and backup stop valve
(3) Downstream of backup stop valve

Sub-subclass 8. Maneuvering room
(1) Through pressure hull
(2) Between hull stop and backup stop valve
(3) Downstream of backup stop valve

Sub-subclass 9. Engine room

a. Upper level
(1) Through pressure hull
(2) Between hull stop and backup stop valve
(3) Downstream of backup stop valve

b. Lower level

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(1) Through pressure hull
(2) Between hull stop and backup stop valve
(3) Downstream of backup stop valve

Sub-subclass 10. Reactor compartment tunnel
(1) Through pressure hull
(2) Between hull stop and backup stop valve
(3) Downstream of backup stop valve

Sub-subclass 11. Reactor compartment lower level
(1) Through pressure hull
(2) Between hull stop and backup stop valve
(3) Downstream of backup stop valve

Sub-subclass 12. Battery well
(1) Through pressure hull
(2) Between hull stop and backup stop valve
(3) Downstream of backup stop valve

Subclass C - Atmosphere Control and Toxic Gas Contamination Casualties

Sub-subclass 1. Lack of oxygen
Sub-subclass 2. Smoke
Sub-subclass 3. Carbon monoxide
Sub-subclass 4. Carbon dioxide
Sub-subclass 5. Ozone
Sub-subclass 6. Sulfuric acid fumes
Sub-subclass 7. Chlorine
Sub-subclass 8. Hydrocarbon gases
Sub-subclass 9. Acrolein
Sub-subclass 10. Arsine/stibine
Sub-subclass 11. Amine vapor
Sub-subclass 12. Hydrochloric acid fumes
Sub-subclass 13. Phosgene
Sub-subclass 14. Freon
Sub-subclass 15. Acetylene
Sub-subclass 16. Acetone
Sub-subclass 17. Selenium

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Sub-subclass 18. Mercury

Sub-subclass 19. Hydrogen sulfide

Sub-subclass 20. Excessive hydrogen

Sub-subclass 21. Excessive nitrogen

Sub-subclass 22. Mustard gas

Sub-subclass 23. Tear gas

Sub-subclass 24. Lewisite gas

Sub-subclass 25. Nerve gas

Subclass D - Collision/grounding

Sub-subclass 1. Surfaced

a. Noncompliance with rules of the road

b. Faulty navigation

c. Improper control setting

d. Sensor error/failure

Sub-subclass 2. Submerged

a. Noncompliance with rules of the road

b. Faulty navigation

c. Improper control setting

d. Sensor error/failure

Subclass E - Personal Safety/Personnel Casualties

Sub-subclass 1. Electric/shock

Sub-subclass 2. Drowning

Sub-subclass 3. Injury from rotating machinery

Sub-subclass 4. Injury from tool use

Sub-subclass 5. Man left on bridge or main deck

Sub-subclass 6. Skin burns

Subclass F - Escape and Rescue Casualties

Sub-subclass 1. Equipment failure(s)

Sub-subclass 2. Improper procedure(s)

CLASS III - POWER PLANT CASUALTY EFFECTS

Subclass A - Propulsion Casualties

Sub-subclass 1. One main engine fails

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a. One drive, one drag

b. One drive, one stopped and mechanically disconnected from bull gear

Sub-subclass 2. Two main engines and/or bull gear fail

Sub-subclass 3. Electric propulsion motor (EPM) fails

a. Electrical failure

b. Mechanical failure (armature will not rotate)

Sub-subclass 4. Secondary propulsion motor (SPM) system failure

a. Electrical failure

b. Hydraulically and mechanically locked in extended position

c. Hydraulically and mechanically locked in raised position

Sub-subclass 5. Propulsion drive failure

a. Excessive stern tube leakage or flooding

b. Shafting parts aft of thrust bearing

c. Thrust bearing fails

d. Propeller failure

(a) One or more blades broken off

(b) Propeller falls off

Subclass B - High-Radiation Casualty

Sub-subclass 1. Forward of reactor compartment

Sub-subclass 2. Reactor compartment tunnel

Sub-subclass 3. AMS or AMR No. 2

Sub-subclass 4. Engine room

Subclass C - Major Steam Leak

Sub-subclass 1. On upstream side of main steam cut-out valve

Sub-subclass 2. On downstream side of main steam cut-out valve

Subclass D - Reactor Emergency

Sub-subclass 1. Requires single-loop operation

Sub-subclass 2. Requires complete shutdown

Sub-subclass 3. Requires poison

Subclass E - Primary Coolant Leak

Sub-subclass 1. Major leak

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a. Reactor compartment lower level
b. Reactor compartment tunnel
c. AMS/AMR No. 2 lower level
d. AMS/AMR No. 2 upper level

Sub-subclass 2. Minor leak

a. Reactor compartment lower level
b. Reactor compartment tunnel
c. AMS/AMR No. 2 lower level
d. AMS/AMR No. 2 upper level

Subclass F - Electric Plant Failures

Sub-subclass 1. Lose one ship's-service turbine generator (SSTG)

a. One running
b. Two running

Sub-subclass 2. Lose two SSTG's

Sub-subclass 3. Lose one ship's-service motor generator (SSMG)

a. One running
b. Two running

Sub-subclass 4. Lose two SSMG's

Sub-subclass 5. Lose MG busses

Sub-subclass 6. Lose starboard DC bus

Sub-subclass 7. Lose port DC bus

Sub-subclass 8. Lose battery bus

Sub-subclass 9. Lose diesel generator

a. Surfaced
b. Submerged

Sub-subclass 10. Lose one 400-cps M/G

a. One running
b. Two running

Sub-subclass 11. Lose two 400-cps M/G

Sub-subclass 12. Lose 60-cps 1C SWBD

Sub-subclass 13. Lose 400-cps 1C SWBD

APPENDIX C
CASUALTY CLASSIFICATION

			Degree of criticality[a]
CLASS I - SHIP COMMAND AND CONTROL			
Subclass A - Stern Plane Casualties			
Sub-subclass 1.	Fail on dive		
	a.	Mechanical jamming	1 and 2
	b.	Electrohydraulic	2 and 3
	c.	Indication	4 and 5
Sub-subclass 2.	Fail on rise		
	a.	Mechanical jamming	3
	b.	Electrohydraulic	3 and 4
	c.	Indication	4 and 5
Subclass B - Fairwater Plane Casualties			
Sub-subclass 1.	Fail on dive or rise		
	a.	Mechanical jamming	3
	b.	Electrohydraulic	3 and 4
	c.	Indication	4 and 5

[a]The degree of criticality is defined below:

Code no.	
1	Immediately commence emergency main ballast tank blow to surface or periscope depth to control casualty and/or reduce its severity.
2	Immediately commence normal main ballast tank blow and conduct normal surface <u>or</u> come to periscope depth or some other safe depth less than 200 ft to control casualty and/or reduce its severity.
3	Deliberate ship control action may be required to ensure safe ship operations. System functions must be restored immediately.
4	Ship control action not immediately required. System functions must be restored immediately.
5	Continue operations. Immediate action not required.

APPENDIX C

			Degree of criticality
Subclass C -	Steering System Casualties		
Sub-subclass 1.	Rudder system		
	a.	Mechanical jamming	3 and 4
	b.	Electrohydraulic	3 and 4
	c.	Indication	4 and 5
Sub-subclass 2.	Compass system		4 and 5
Subclass D -	Main Ballast Tank Blow Systems Casualties		
Sub-subclass 1.	Forward group NORMAL		
	a.	Electrical	1 and 4
	b.	Mechanical	1 and 4
	c.	Indication	4
Sub-subclass 2.	After group NORMAL		
	a.	Electrical	1 and 4
	b.	Mechanical	1 and 4
	c.	Indication	4
Sub-subclass 3.	Forward group EMERGENCY		
	a.	Electrical	2 and 3
	b.	Mechanical	2 and 3
	c.	Emergency flask	2 and 4
	d.	Indication	4
Sub-subclass 4.	After group EMERGENCY		
	a.	Electrical	2 and 3
	b.	Mechanical	2 and 3
	c.	Emergency flask	2 and 4
	d.	Indication	4
Sub-subclass 5.	Low-pressure blower		
	a.	Electrical	5
	b.	Mechanical	5
	c.	Indication	5
Sub-subclass 6.	Diesel engine blow		5

APPENDIX C

				Degree of criticality
Subclass E - Main Ballast Tank Vent System Casualties				
Sub-subclass	1.	Vents OPEN		
		a.	Mechanical	4
		b.	Electrohydraulic	4
		c.	Indication	5
Sub-subclass	2.	Vents SHUT		
		a.	Mechanical	5
		b.	Electrohydraulic	5
		c.	Indication	5
Subclass F - Variable Ballast Tank Systems (Excluding Trim Pump and Hovering System) Casualties				
Sub-subclass	1.	a.	Mechanical	5
		b.	Electrical	5
		c.	Indication	5
Subclass G - Hovering System Casualties (SSN-637 Class and SSBN's only)				
Sub-subclass	1.	a.	Mechanical	3 - 5
		b.	Electrical	3 - 5
		c.	Indication	4 and 5
Subclass H - Trim Pump System Casualties				
Sub-subclass	1.	a.	Mechanical	3 - 5
		b.	Electrical	3 - 5
		c.	Indication	4 and 5
Subclass I - Negative Tank System Casualties (SSN's only)				
Sub-subclass	1.	a.	Mechanical	3 and 4
		b.	Electrohydraulic	3 and 4
		c.	Indication	4
		d.	High-pressure air	3 and 4
		e.	Low-pressure air	4 and 5

APPENDIX C

			Degree of criticality
Subclass J - Mast System Casualties			
Sub-subclass 1.	ECM mast		5
Sub-subclass 2.	Antenna masts		4
Sub-subclass 3.	Radar mast		5
Sub-subclass 4.	Periscopes		4 and 5
Subclass K - Automatic Maneuvering Control System Casualties			4 and 5
Subclass L - Interior Communication System Casualties			
Sub-subclass 1.	Alarm systems		
	a.	Collision alarm	3 and 4
	b.	Power plant emergency alarm	3 and 4
	c.	Diving/surfacing alarm	3 and 5
	d.	General alarm	4 and 5
Sub-subclass 2.	MC systems		
	a.	1, 2, 4, and 7 MC systems	4
	b.	Other MC systems	4 and 5
Sub-subclass 3.	Sound-powered telephone circuits		
	a.	JA, X60J, and X1J or dial telephone	3 and 4
	b.	Other SP circuits	4
Subclass M - Snorkel System Casualties			
Sub-subclass 1.	Induction mast system (including head valve)		3
Sub-subclass 2.	Safety circuit and altimeter		3
CLASS II - GENERAL EMERGENCIES			
Subclass A - Fire			
Sub-subclass 1.	Class A		2 - 5
Sub-subclass 2.	Class B		2 - 4
Sub-subclass 3.	Class C		2 - 5
Sub-subclass 4.	Oxygen or other combustible gases		1 - 3

APPENDIX C

			Degree of criticality
Subclass B - Flooding			
Sub-subclass	1.	Leakage	4 and 5
Sub-subclass	2.	Flooding	1 - 3
Subclass C - Atmosphere Control and Toxic-Gas-Contamination Casualties			
Sub-subclass	1.	Antipersonnel or war gases	2
Sub-subclass	2.	Smoke	2
Sub-subclass	3.	Lack of oxygen	3
Sub-subclass	4.	Excessive carbon dioxide	3
Sub-subclass	5.	Excessive hydrogen	1 and 2
Sub-subclass	6.	Excessive oxygen	1 and 2
Sub-subclass	7.	Other gases or gaseous products of decomposition	2 - 4
Sub-subclass	8.	Temperature/humidity	4 and 5
Subclass D - Collision/Grounding			
Sub-subclass	1.	Surfaced	2
Sub-subclass	2.	Submerged	1 and 2
Subclass E - Personnel Casualties			
Sub-subclass	1.	Electric shock	4
Sub-subclass	2.	Drowning	4
Sub-subclass	3.	Injury from rotating machinery	4
Sub-subclass	4.	Injury from tool use	4
Sub-subclass	5.	Man left on bridge or main deck	2
Sub-subclass	6.	Burns	4
CLASS III - POWER PLANT CASUALTY EFFECTS			
Subclass A - Propulsion System Casualties			
Sub-subclass	1.	One main engine fails	3 and 4
Sub-subclass	2.	Two main engines or bull gear or clutch fails	2
Sub-subclass	3.	Electric propulsion motor (EPM)	
		a. Electrical failure	4

			Degree of criticality
		b. Mechanical failure (armature will not rotate)	2 and 3
Sub-subclass	4.	Propulsion drive failures	
		a. Propeller failure	2
		b. Shafting frozen/seizure	2
		c. Shafting parted	
		(1) Forward of shaft seal	1 and 2
		(2) Aft of shaft seal	2
Sub-subclass	5.	Secondary propulsion motor (SPM)	
		a. Electrical failure	4 and 5
		b. Hydraulically and mechanically locked in extended position	3 and 4
		c. Hydraulically and mechanically locked in the raised position	4 and 5
Subclass B - Major Steam Leak			
Sub-subclass	1.	On upstream side of main steam cutout valve	2 and 3
	2.	On downstream side of main steam cutout valve	3
Subclass C - Steam Generation/Heat Source Casualties			
Sub-subclass	1.	Heat source temporary loss (less than one hour)	3
Sub-subclass	2.	Heat source permanent loss (greater than one hour)	2 and 3
Sub-subclass	3.	Failure of any steam generator or its heat source	3
Subclass D - Electric Plant Failures			
Sub-subclass	1.	One ship's-service turbine generator (SSTG) fails	
		a. One running	3
		b. Two running	5
Sub-subclass	2.	One ship's-service motor generator (SSMG) fails	4
Sub-subclass	3.	Lose one vital bus (MG)	3
Sub-subclass	4.	Lose two vital busses (MG)	2

APPENDIX C

		Design of criticality
Sub-subclass 5.	Lose one semivital bus (TG)	2
Sub-subclass 6.	Lose two semivital busses (TG)	4
Sub-subclass 7.	Lose port DC bus	4
Sub-subclass 8.	Lose starboard DC bus	3
Sub-subclass 9.	Lose battery bus	3
Sub-subclass 10.	Lose diesel generator-surfaced	
	a. Steam plant on line	5
	b. Steam plant secured	4
Sub-subclass 11.	Lose diesel generator - submerged	
	a. Steam plant on line	4
	b. Steam plant secured	2
Sub-subclass 12.	Lose one 400-cps motor generator	
	a. One running	3
	b. Two running	5
Sub-subclass 13.	Lose 60-cps interior communication switchboard	2
Sub-subclass 14.	Lose 400-cps interior communication switchboard	3
Sub-subclass 15.	Lose normal lighting	4
Sub-subclass 16.	Lose emergency lighting	2 - 4

APPENDIX D
SEQUENCE AND TASK ANALYSIS

I - SHIP COMMAND AND CONTROL

A - STERN PLANES FAIL ON DIVE

1. RECOGNITION

a. Initial Conditions - Diving officer (DO) and/or planesman are cognizant of ordered and actual speed, depth, depth rate, attitude, turn rate, trim, and hydraulic system status.

b. Detection

(1) Detection of Impending Casualties - BCPO notes abnormal hydraulic indications.

(2) Detection of Existing Casualties - If attitude change is ordered, DO and planesman note that the plane angle indicators do not respond or are erratic. This is followed by feel and indicated depth and attitude changes; lag will vary from 0.5 to 5.0 sec. Other indications may be a hydraulic or electric alarm.

If a steady state is desired, the planesman notes that the plane angle indicator is not consistent with control position. Both the DO and planesman note erratic indications or a hydraulic or electric alarm. Both subsequently note feel and indicated attitude changes; lag varies from 0.5 to 5.0 sec.

c. Verification - The DO, supported by detailed SP and BCPO checks, verifies that a stern plane casualty exists. The DO immediately checks the emergency stern plane indicator, and assesses trim and maneuver effects. Checks by the DO involve short delays and include checking hydraulic control in the emergency mode, and checking changes in ship's speed and attitude.

2. DECISION MAKING (DO/OOD)

a. Ship Characteristics - Rate of change and current values of speed, depth, attitude, and turn and plane angle are noted.

b. Crew Characteristics - Crew capability, state of training, physiological/psychological condition, and reaction time are noted.

c. System Status - Status of essential ship systems is noted. DO assesses fairwater planes, hydraulics, and MBT blow. OOD assesses fairwater planes, hydraulics, MBT blow, rudder, propulsion, engine telegraph order, 1 MC and 7 MC, and sound-powered phone.

APPENDIX D

d. Recall Appropriate Data - Recall special instructions, ship's standing orders and other constraints, for example, minimum depth, ice overhead, and surface ship activity.

e. Recall Available Courses of Action - The available courses of action are fairwater planes, fishtail rudder (or hard right or left), emergency back, MBT blow, emergency plane control, manual plane control, correct stern plane problem, and none.

f. Data Collation - The information of 2a through 2d are compared with the alternatives of 2e.

g. Course of Action Selection - The course of action is selected from (2)(f).

h. Command Decision - DO receives direction from OOD and modifies or retains the decision of 2g.

3. CORRECTIVE ACTION

a. Basic Sequence - DO orders MBT blow and fairwater planes full rise. OOD orders speed back full and fishtail the rudder. OOD notifies engine room of failure.

b. Representative Alternative Actions - Depending on depth,[a] tactical situation, and special instructions, the DO/OOD may elect to avoid noise or broaching by some combination of delay MBT blow or speed change; engines, all stop, then full back; rudder - leave amidship, hard right or hard left; flood variable ballast tanks; cycle MBT vents; and flood negative.

If the stern planes fail at a small angle, at moderate or shallow depth, and low ship angle, DO/OOD may elect to attempt to free the stern planes and/or use fairwater planes - rise only.

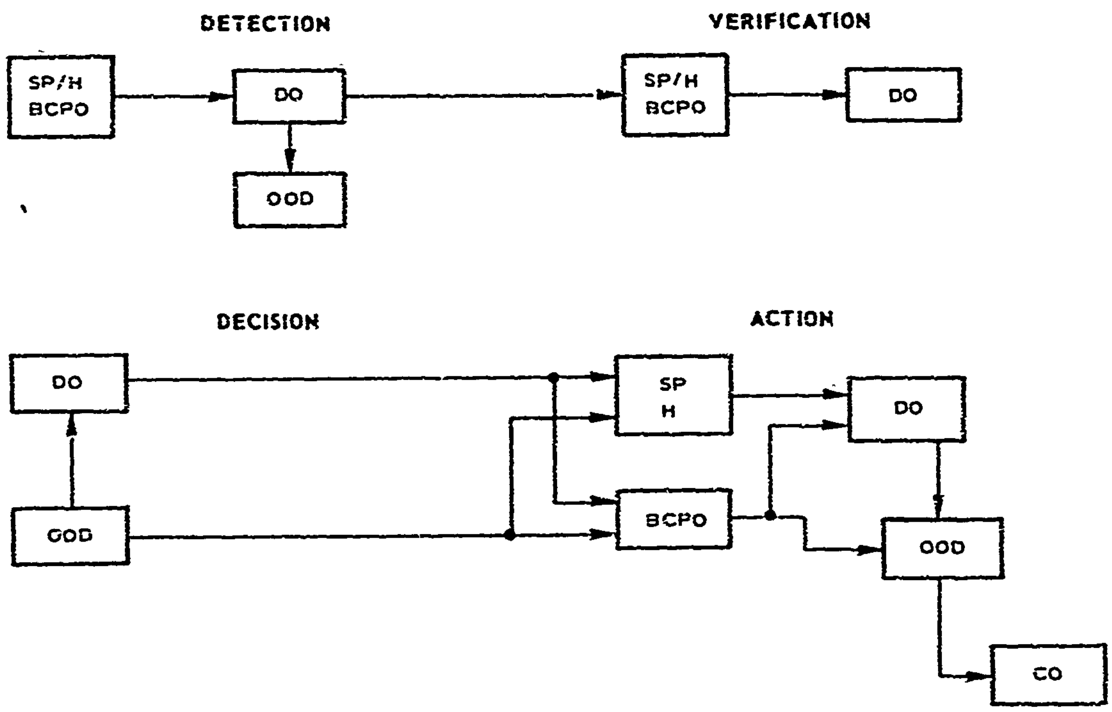
If hydraulic failure is indicated and ship conditions permit, DO/OOD will elect to have planesmen switch hydraulics to emergency or manual mode as the primary initial action.

If indicator failure only, DO/OOD will elect to have planesmen use emergency indicator only. The DO may have phones manned in engine room to monitor stern plane ram indicator.

[a]If failure occurs at shallow depth, an increase in depth may be desirable to avoid broaching.

APPENDIX D

4. INFORMATION FLOW DIAGRAM



5. FOLLOWON ACTION/FEEDBACK

a. Results - Indication of Results of Initial Action

(1) Operator Response - Personnel who will indicate satisfactory execution of orders and/or status of systems for which they are responsible are the DO, EOOW, SP, H, and BCPO/COW.

(2) CO Response - The CO may, at his option, elect to supplement or modify the actions of the DO or OOD.

(3) Ship Response

(a) Variables of 2a and 2c, above.

(b) Trim and negative tank (hovering system on SSBN's) status.

b. Determine Supplemental Actions Required - Possibilities include change from limited action of 3b to full action of 3a.

APPENDIX D

c. Indication of Followon results

(1) CO Response (Directives) - The CO may, at his option elect to supplement or modify the actions of the DO/OOD.

(2) Ship Status - Followon conditions of basic recovery procedure are positive buoyancy, decreasing depth, decreasing down angle, speed $\leq$ 5 knots, and depth $\cong$ 400 ft (assuming ascent from deeper depths.) Followon conditions of alternate recovery procedures are negative buoyancy, increasing depth, decreasing down angle, and decreasing speed.

d. Determine Action Required to Complete Recovery - Desired (safe) operating envelope and action required are identified.

e. Complete Casualty Recovery

Representative action for completion of basic recovery procedures are

1. Secure blow and adjust trim to level off at desired depth consistent with tactical situation
2. Engines, all stop
3. Rudder amidship

Representative action for completion of alternate recovery procedures are

1. Shut MBT vents
2. Blow MBT
3. Pump trim tanks to sea
4. Blow and vent negative (or hovering tanks)

Final action consists of rigging for ship operation within a safe operating envelope.

B - STERN PLANES FAIL ON RISE

1. RECOGNITION

a. Initial Conditions - Diving officer (DO) and/or planesmen are cognizant of ordered and actual speed, depth, rise rate, attitude, turn rate, trim, and hydraulic system status.

b. Detection

(1) Detection of Impending Casualties - BCPO notes abnormal hydraulic indications.

(2) Detection of Existing Casualties - If attitude change is ordered, DO and planesmen note that the plane angle indicators show no response or are erratic. This is followed by feel and indicated depth and attitude changes; lag varies from 0.5 sec to 5 sec. Other indications may be a hydraulic or electric alarm.

If a steady state is desired, planesmen note that the plane angle indicator is not consistent with control position. Both the DO and planesmen note erratic indications or hydraulic or electric alarm. Both subsequently note "fee" and indicated attitude changes; lag varies from 0.5 sec to 5 sec.

c. Verification

The DO, supported by detailed SP and BCPO checks, verifies that a stern plane casualty exists.

DO immediately checks emergency stern plane indicator and assess trim and maneuver effects. Checks by DO that involve short delays include checking hydraulic control in the emergency mode and checking changes in ship's speed and attitude.

2. DECISION MAKING (DO AND OOD)

a. Ship Characteristics - Rate of change and current values of speed, depth, attitude, turn, and plane angle are noted.

b. Crew Characteristics - Crew capability, state of training, physiological/psychological condition, and reaction time are assessed.

c. System Status - Status of essential ship systems is determined. DO assesses fairwater planes, hydraulics, and MBT blow. OOD assesses fairwater planes, hydraulics, MBT blow, propulsion, engine telegraph order and 1 MC and 7 MC and sound-powered phone.

d. Recall Appropriate Data - Special instructions, ship's standing orders, and other constraints, for example, minimum depth, ice overhead, and surface ship activity are recalled.

e. Recall Available Courses of Action - Available courses of action are fishtail rudder (or hard right or left), emergency back, position fairwater planes for full dive, emergency plane control, manual plane control, and correct stern plane problem and none.

f. Data Collation - Information of 2a through 2d are collated against alternatives of 2e.

g. Course of Action Selection - Course of action is selected from 2f.

APPENDIX D

h. Command Decision - DO receives direction from OOD and modifies or retains decision of 2g.

3. CORRECTIVE ACTION

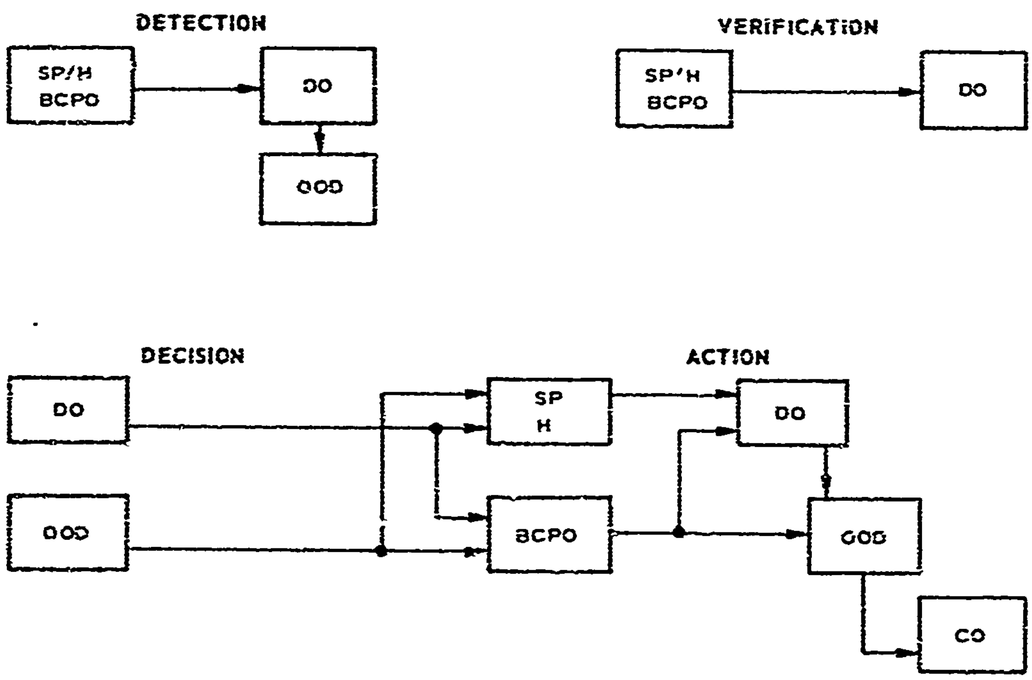
a. Basic Sequence - DO orders fairwater planes full dive. OOD orders speed back full and fishtail the rudder. OOD notifies engine room of failure.

b. Representative Alternative Actions - Depending on depth, tactical situation, and special instructions, the DO/OOD may elect to avoid broaching by some combination of (1) delay speed reversal, (2) engines, all stop, then back full; (3) rudder - leave amidship, hard right, or hard left; (4) flood variable ballast tanks; and (5) flood negative (SSN only). If stern planes fail at a small angle, at moderate or shallow depth and low ship angle, DO/OOD may elect to attempt to free the stern planes and/or use bow planes dive only (from basic sequence).

If hydraulic failure is indicated, and ship conditions permit, DO/OOD will elect to have planesmen switch hydraulics to emergency or manual mode as the primary initial action.

If indicator failure only, DO/OOD will elect to have planesmen use emergency indicator only. The DO may have phones manned in the engine room to monitor stern plane ram indicator.

4. INFORMATION FLOW DIAGRAM



APPENDIX D

5. FOLLOWON ACTION/FEEDBACK

a. Results - Indications of Results of Initial Action

(1) Operator Response - Personnel who will indicate satisfactory execution of orders and/or status of systems for which they are responsible are the DO, EOOW, SP, H, AND BCPO/COW.

(2) CO Response - The CO may at his option elect to supplement or modify the actions of the DO or OOD.

(3) Ship Response

(a) Variables of 2a and 3 c.

(b) VBT and negative tank (hovering system on SSBn's) status

b. Determine Supplemental Actions Required - Possibilities include change from limited action of 3b to full action of 3a.

c. Indication of Followon Results

(1) CO Response (Directives) - The CO may at his option elect to supplement or modify the actions of DO or OOD.

(2) Ship Status - Followon conditions of basic recovery procedure are negative buoyancy, stable or increasing depth, decreasing speed, decreasing up angle, speed ≤ 5 knots, and depth ≈ 400 ft, assuming ascent from deeper depths. Followon conditions of alternate recovery procedures are negative buoyancy, stable or increasing depth, decreasing up angle, decreasing speed.

d. Determine Action Required to Complete Recovery - Desired (safe) operating envelope and action required are identified.

e. Complete Casualty Recovery

Representative action for completion of basic recovery procedures are

1. Adjust trim to level off at desired depth consistent with tactical situation
2. Engines, all stop
3. Rudder amidship,

Representative action for completion of alternate recovery procedures are

1. Adjust trim as required
2. Blow and vent negative (or hovering tanks)

APPENDIX D

Final action consists of rigging for ship operation within a safe operating envelope.

C - FAIRWATER PLANES FAIL ON DIVE

1. RECOGNITION

a. Initial Conditions - Diving officer (DO) and/or planesmen are cognizant of ordered and actual speed, depth, depth rate, attitude, turn rate, trim, and hydraulic system status.

b. Detection

(1) Detection of Impending Casualties - BCPO notes abnormal hydraulic indications.

(2) Detection of Existing Casualties - If depth change is ordered, DO and planesmen note that the plane angle indicators do not respond or are erratic. This is followed by feel and indicated attitude and depth changes; lag varies from 0.5 sec to 5.0 sec. Other indications may be a hydraulic or electric alarm or an audible change in the noise of hydraulic fluid flow.

If a steady state is desired, planesmen note that the angle indicator is not consistent with control position. Both the DO and planesmen note erratic indications or hydraulic or electric alarm. Both subsequently note "feel" and indicated attitude changes; lag varies from 0.5 sec to 5.0 sec. SP may have difficulty in reaching and holding ordered attitude.

c. Verification

The DO, supported by detailed H and BCPO checks, verifies that a fairwater plane casualty exists. DO immediately checks emergency fairwater plane indicator and assesses trim and maneuver effects. Checks by DO involve short delays, checking hydraulic control in the emergency mode, and checking changes in ship's speed and attitude.

2. DECISION MAKING (DO/OOD)

a. Ship Characteristics - Rate of change and current values of speed, depth, attitude, and turn and plane angle are noted.

b. Crew Characteristics - Crew capability, state of training, physiological/psychological condition, and reaction time are assessed.

c. System Status - Status of essential ship systems is assessed. DO assesses stern planes, hydraulics, and MBT blow. OOD assesses

APPENDIX D

stern planes, hydraulics, MBT blow, rudder, propulsion, engine order telegraph, 1 MC and 7 MC, and sound-powered phone.

d. Recall Appropriate Data - Special instructions, ship's standing orders, and other constraints, are recalled, for example, minimum depth, surface-ship activity, and ice overhead.

e. Recall Available Courses of Action - The available courses of action are stern planes rise, fishtail rudder, emergency back, MBT blow, emergency control, manual control, correct fairwater, plane problem, and none.

f. Data Collation - The information of 2a through 2d are collated against alternatives of 2e.

g. Course of Action Selection - Course of action is selected from 2f.

h. Command Decision - DO receives direction from OOD and modifies or retains decision of 2g.

3. CORRECTIVE ACTION

a. Basic Sequence - DO orders stern planes positioned to minimize depth excursion and OOD notifies engine room of failure.

b. Representative Alternative Actions - Depending on depth, tactical situation, and special instructions the DO/OOD may elect to avoid noise or broaching by some combination of (1) delay blow MBT; (2) speed all stop, then back full; (3) fishtail rudder; and (4) flood negative.

If fairwater plane fails at a small angle, at moderate or shallow depth and low ship angle, DO/OOD may elect to attempt to free the fairwater planes before employing the stern planes.

If hydraulic failure is indicated and ship conditions permit, DO/OOD will elect to have planesmen switch hydraulics to emergency or the manual mode as the primary initial action.

If indicator failure only, DO/OOD will elect to have planesmen use emergency indicator only. The DO may have phones manned in engine room to monitor fairwater plane ram indicator.

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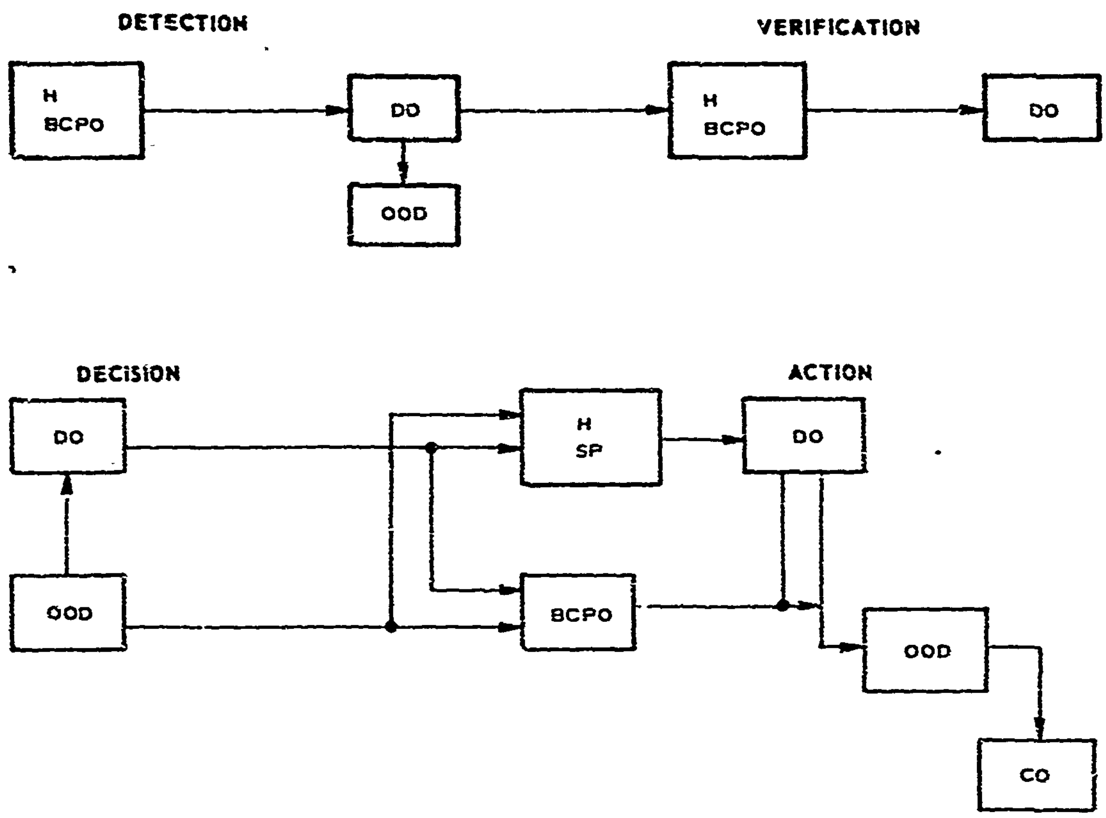
4. INFORMATION FLOW DIAGRAM



5. FOLLOWON ACTION/FEEDBACK

a. <u>Results - Indication of Results of Initial Action</u>

(1) Operator Response - Personnel who will indicate satisfactory execution of orders and/or status of systems for which they are responsible are the DO, EOOW, H. SP, and BCPO/COW.

(2) CO Response - The CO may, at his option, elect to supplement or modify the actions of the DO or OOD.

(3) Ship Response

(a) Variables of 2a and 2c.

(b) Variable and negative tank status

b. <u>Determine Supplemental Actions Required</u> - Possibilities include change from limited action of 3b to full action of 3a.

APPENDIX D

c. Indication of Followon Results

(1) CO Response (Directives) - The CO may, at his option, elect to supplement or modify the actions of the DO/OOD.

(2) Ship Status - Followon conditions of recovery procedure are slight change in buoyancy, decreasing depth, decreasing down angle, speed $\leq$ 5 knots, and depth $\cong$ 400 ft (assuming ascent from deeper depths). Followon conditions of alternate recovery procedures are positive buoyancy, decreasing depth, decreasing speed, and decreasing down angle.

d. Determine Action Required to Complete Recovery - Desired (safe) operating envelope and action required are identified.

e. Complete Casualty Recovery

Representative action for completion of recovery procedures is to adjust stern planes and trim to level off at desired depth consistent with tactical situation.

Representative action for completion of alternate recovery procedures are

1. Secure blow and adjust trim to level off at a desired depth consistent with tactical situation
2. Engines, all stop
3. Rudder amidship
4. Blow and vent negative (or hovering tanks).

Final action is to rig for ship operation within a safe operating envelope.

D - FAIRWATER PLANES FAIL ON RISE

1. RECOGNITION

a. Initial Conditions - Diving officer (DO) and/or planesmen are cognizant of ordered and actual speed, depth, depth rate, attitude, turn rate, trim, and hydraulic system status.

b. Detection

(1) Detection of Impending Casualties - BCPO notes abnormal hydraulic indications.

(2) Detection of Existing Casualties - If depth change is ordered, DO and planesmen note that plane angle indicators do not respond or

are erratic. This is followed by feel and indicated attitude and depth changes; lag varies from 0.5 sec to 5.0 sec. Other indications may be a hydraulic or electric alarm.

If a steady state is desired, planesmen note that the plane angle indicator is not consistent with control position. Both DO and planesmen note erratic indications or hydraulic or electric alarm. Both are subsequently followed by feel and indicated attitude and depth changes; lag varies from 0.5 sec to 5.0 sec. SP may have difficulty in reaching and holding ordered attitude.

c. Verification - DO supported by detailed H and BCPO checks will verify that a fairwater plane casualty exists.

DO immediately checks emergency fairwater plane indicator and assesses trim and maneuver effects. Checks by DO that will involve short delays include checking hydraulic control in the emergency mode and checking changes in ship's speed and attitude.

2. DECISION MAKING (DO/OOD)

a. Ship Characteristics - Rate of change and current values of speed, depth, attitude, turn, and plane angle are noted.

b. Crew Characteristics - Crew capability, state of training, physiological/psychological condition, and reaction time is assessed.

c. System Status - Status of essential ship's systems is assessed. DO assesses stern planes, hydraulics, and MBT blow. OOD assesses stern planes, hydraulics, MBT blow, rudder, propulsion, engine order telegraph, 1 MC and 7 MC and sound-powered phone.

d. Recall Appropriate Data - Special instructions, ship's standing orders, and other constraints, for example, minimum depth, ice overhead, and surface ship activity, are recalled.

e. Recall Available Courses of Action - The available courses of action are stern planes dive, fishtail rudder, emergency back, emergency control, manual control, correct fairwater plane problem and none.

f. Data Collation - The information of 2a through 2d are collated against alternatives of 2e.

g. Course of Action Selection - Course of action is selected from 2f.

h. Command Decision - DO receives direction from OOD and modifies or retains decision of 2g.

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3. CORRECTIVE ACTION

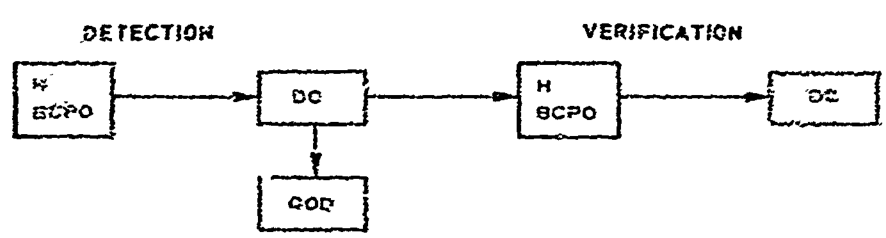
a. Basic Sequence - DO orders stern planes positioned to minimize ascent. OOD notifies engine room of failure.

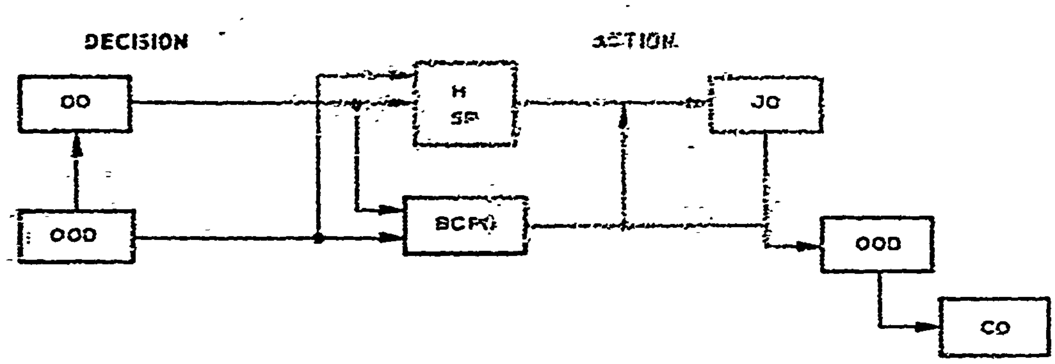
b. Representative Alternative Actions - Depending on depth, tactical situation and special instructions the DO/OOD may elect to avoid noise or broaching by some combination of (1) delay speed reversal, (2) engines all stop, then back full, (3) fishtail rudder, (4) flood VBT, and (5) flood negative. If fairwater plane fails at a small angle, at a moderate or shallow depth and low angle, DO/OOD may elect to attempt to free the fairwater planes before employing stern planes.

If hydraulic failure is indicated and ship conditions permit, DO/OOD will elect to have planesmen switch hydraulics to emergency or manual mode as the primary initial action.

If indicator failure only, DO/OOD elects to have planesmen use the emergency indicator only. The DO may have phones manned in the engine room to monitor fairwater plane ram indicator.

4. INFORMATION FLOW DIAGRAM





APPENDIX D

5. FOLLOWON ACTION/FEEDBACK

a. Results - Indication of Results of Initial Action

(1) Operator Response - Personnel who will indicate satisfactory execution of orders and/or status of systems for which they are responsible are the DO, EOOW, H, SP, and BCPO/COW.

(2) CO Response - The CO may, at his option, elect to supplement or modify the actions of the DO or OOD.

(3) Ship Response

(a) Variables of 2a and 2c.

(b) Trim and negative tank (hovering system on SSBN's) status.

b. Determine Supplemental Actions Required - Possibilities include change from limited action of 3b to full action of 3a.

c. Indication of Followon Results

(1) CO Response (Directives) - The CO may, at his option, elect to supplement or modify the actions of the DO/OOD.

(2) Ship Status - Followon conditions of recovery procedures are decreasing depth, decreasing speed, decreasing up angle, slight change in buoyance, speed ≤ 5 knots, and depth $\cong 400$ ft (assuming ascent from deeper depths). Followon conditions of alternate recovery procedures are negative buoyancy, increasing depth, decreasing speed, and decreasing up angle.

d. Determine Action Required to Complete Recovery - Desired (safe) operating envelope and action required are identified.

e. Complete Casualty Recovery

Representative action for completion of recovery procedure is to adjust stern planes and trim to level off at a desired depth consistent with tactical situation.

Representative action for completion of alternate recovery procedures are (1) adjust trim to level off at a desired depth consistent with tactical situation, (2) engines all stop, (3) rudder amidship, (4) vent VBT, and (5) blow and vent negative. Final action is to rig for ship operation within a safe operating envelope.

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E - RUDDER FAILURE

1. RECOGNITION

a. Initial Conditions - Diving officer (DO) and/or helmsman are cognizant of ordered and actual speed, depth, depth rate, attitude, turn rate, trim, hydraulic system status, and the navigational and tactical situation.

b. Detection

(1) Detection of Impending Casualties - BCPO notes abnormal hydraulic indications.

(2) Detection of Existing Casualties - If course (turn) change is ordered, DO and helmsman note that rudder angle indicators do not respond or are erratic. This is followed by feel and indicated course and attitude changes; lag will vary from 0. 5 to 5. 0 sec. Other indications may be a hydraulic or electric alarm.

If a steady state is desired, helmsman notes that the rudder angle indicator is not consistent with control position. Both the DO and helmsman note erratic indications or a hydraulic or electric alarm. Both subsequently note feel and indicated course and attitude changes; lag varies from 0. 5 to 5. 0 sec.

c. Verification - The DO, supported by detailed helmsman and BCPO checks, verifies that a rudder casualty exists. DO immediately checks emergency rudder position indicator and assesses trim and maneuver effects.

Checks by DO that will involve short delays include checking hydraulic control in the emergency mode and checking changes in ship's speed, depth, and course.

2. DECISION MAKING (DO/OOD)

a. Ship Characteristics - Rate of change and current values of speed, depth, attitude, and turn and rudder angle are noted.

b. Crew Characteristics - Crew capability, state of training, physiological/psychological condition, and reaction time are assessed.

c. System Status - Status of essential ship systems are assessed. DO assesses stern planes, fairwater planes, hydraulics, MBT blow. OOD assesses stern planes, fairwater planes, hydraulics, MBT blow, propulsion, engine order telegraph, 1 MC and 7 MC, and sound-powered phone.

d. Recall Appropriate Data - Recall special instructions, ship's

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standing orders and other constraints, for example, minimum depth, ice overhead, and surface-ship activity.

e. Recall Available Courses of Action - The available courses of action are stern plane maneuvering, engines, all stop, emergency control, correct rudder problem, and none.

f. Data Collation - The information of 2a through 2d are collated against alternatives of 2e.

g. Course of Action Selection - Select Course of action is selected from 2f.

h. Command Decision - DO receives direction from OOD and modifies or retains decision of 2g.

3. CORRECTIVE ACTION

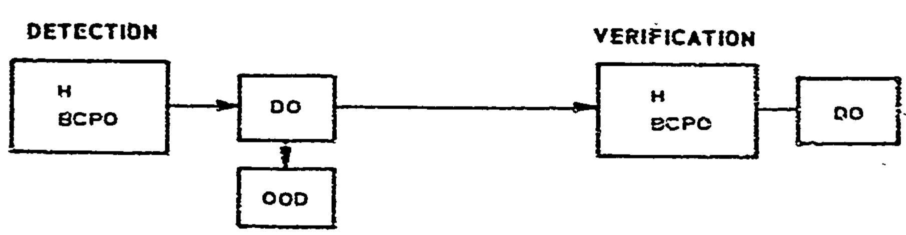
a. Basic Sequence - DO orders speed change and stern planes used to minimize course change, ascent, and roll. OOD notifies engine room of failure.

b. Representative Alternative Actions - Depending on depth, tactical situation, and special instructions, the DO/OOD may elect to avoid noise or broaching by some combination of (1) delay use of stern planes, (2) delay speed stop, (3) flood VBT, and (4) utilize FWP to minimize depth changes. If rudder fails at a small angle, at a moderate or shallow depth or low ship angle, DO/OOD may elect to attempt to free the rudder before employing the stern planes.

If hydraulic failure is indicated and ship conditions permit, DO/OOD will elect to have helmsman switch hydraulics to emergency (emergency positioning pump, stern plane emergency positioning system, vital hydraulic system) mode as the primary initial action.

If indicator failure only, DO/OOD will elect to have helmsmen use emergency indicator only. The DO may have phones manned in the engine room to monitor rudder ram indicator.

4. INFORMATION FLOW DIAGRAM



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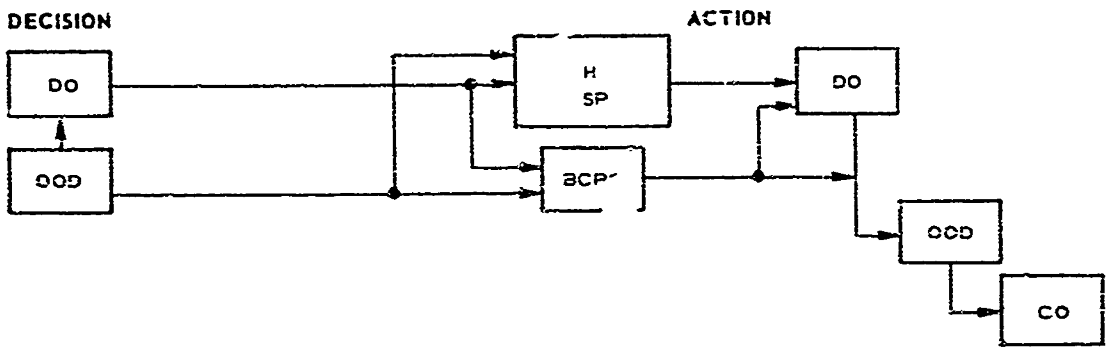

5. FOLLOWON ACTION/FEEDBACK

a. Results - Indication of Results of Initial Action

(1) Operator Response - Personnel who will indicate satisfactory execution of orders and/or status of systems for which they are responsible are the DO, EOOW, H, SP, and BCPO/COW.

(2) CO Response - The CO may, at his option, elect to supplement or modify the actions of the DO or OOD.

(3) Ship Response

(a) Variables of 2a and 2c.

(b) Trim and negative tank (hovering system on SSBN's) status.

b. Determine Supplemental Actions Required - Possibilities include change from limited action of 3b to full action of 3a.

c. Indication of Followon Results

(1) CO Response (Directives) - The CO may, at his option, elect to supplement or modify the actions of the DO/OOD.

(2) Ship Status - Followon conditions of basic recovery procedure are light change of buoyancy, stable or increasing depth, decreasing speed, decreasing up angle, speed $\approx$ 5 knots, and depth $\approx$ 400 ft (assuming ascent from deeper depth). Followon condition of alternate recovery procedures are negative buoyancy, stable or increasing depth, decreasing up angle, and decreasing speed.

d. Determine Action Required to Complete Recovery - Identify desired (safe) operating envelope and identify action required.

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e. Complete Casualty Recovery - Representative action for completion of basic recovery procedures are (1) to adjust trim to level off at desired depth consistent with tactical situation and (2) engines, all stop. Representative action for completion of alternate recovery procedures is to adjust trim as required. Final action is to rig for ship operation within a safe operating envelope.

II - GENERAL EMERGENCY

A - FIRE - OPERATIONS COMPARTMENT, MISSILE COMPARTMENT, AND BOW COMPARTMENT

1. RECOGNITION

a. Initial Conditions - The submarine is assumed to be operating at deep depth. Speed is 8 to 15 knots. Buoyancy is slightly positive.

b. Detection

(1) Detection of Impending Casualties

(a) Indicated or Felt High Temperature - Power distribution boxes, panels and switchboards; fans and heaters; pump bearings; lube and hydraulic oil; hydraulic pumps; washing machines, dryers, fry kettle, ranges and miscellaneous mess or galley equipment; and control panels of electronic equipment.

(b) Abnormal Operation of Equipment

(c) Water Leakage or Flooding - Power distribution boxes, panels or switchboards; control panels; pump motors; fans or heaters; electrical appliances.

(2) Detection of Existing Casualties - Fire is detected visually and by smell by local personnel and watchstanders in the various rooms, spaces, and stations. OOD receives word via 4 MC, 7 MC, or sound-powered phones.

1. Ship control watches at periscope center, diving station, BCP, attack center, navigation center, sonar room, radio room, and control room.
2. Engineering watches at control room.
3. Weapons watches at torpedo room, missile control center, and missile compartment.

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4. Special watches at galley, scullery, ship's office, pantry, control room/sick bay, nucleonics laboratory, and supply office.

c. Verification - Watchstanders make visual and/or tactual checks.

2. DECISION MAKING

a. Local Personnel

(1) Note location, specific equipment involved and type of fire.

(2) Note status and function of affected and adjacent equipment.

(3) Note rate of combustion and location of fire extinguishers.

(4) Recall available courses of action: (1) shutdown affected and adjacent equipment; (2) request additional help; and (3) use extinguisher agents - CO_2, high velocity fog, and water stream.

(5) Collate the information of 2a(1) through 2a(3) against alternatives of 2a(4).

(6) Select the course of action.

(7) OOD receives direction from EOOW or OOD and modifies or retains decision.

b. EOOW

(1) Note information of 2a(1) through 2a(3) and 2a(6) as reported by local personnel.

(2) Estimate effect of fire and local corrective action on electrical, control, navigation, radar/sonar, and weapon systems.

(3) Estimate effect of fire and corrective action on ship's atmosphere.

(4) Assess status of ship systems.

(5) Recall available/mandatory courses of action: (1) supervisory functions: ensure proper execution of 2a(4) and ensure use of EBS/OBA; (2) evacuate compartment of nonwatchstanding personnel and/or all personnel; (3) isolate compartment, includes vent closure; (4) change lineup of equipment; and (5) measures taken for personnel protection and system control if fire is in ship control center.

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c. OOD/DO

(1) Note current speed, depth, attitude, and trim.

(2) Assess crew capability, state of training, physiological/psychological condition and reaction.

(3) Assess status of essential ship's systems; for example, planes and rudder, hydraulics, propulsion, electrical, rig of oil systems, and rig of piping and ventilation systems.

(4) Recall special instructions, ship's standing orders and other constraints; for example, minimum depth, ice overhead, and surface ship activity.

(5) Recall available/mandatory courses of action; for example, change of depth, change of speed, rig for reduced electrical power, notify ship's in vicinity, isolate ventilation systems, prepare for surfacing, and secure oxygen bleed.

(6) Evaluate courses of action taking into account the seriousness of the fire and readiness to meet a subsequent casualty which may result from the fire.

(7) Select the course of action from 2c(5) and 2c(6).

(8) OOD receives information from EOOW and DO and direction from CO and XO. He may then be required to modify his decision.

3. CORRECTIVE ACTION

a. Basic Sequence

(1) Local Personnel

(a) Shut down affected and adjacent equipment where local control if feasible. Request assistance in securing equipment which is remotely controlled or not accessible because of the fire. Electrical isolation should be accomplished at the nearest accessible panel or switchboard.

(b) Apply dry chemical fire extinguisher for controllable electrical, grease, or oil fires that are accessible. If inaccessible, use the CO_2 extinguisher.

(c) Request assistance and use high pressure fog if fire is not controllable by 3a(1)(b).

(d) Use the EBS/OBA if fire becomes large.

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(2) COOW

(a) Pass the word via voice to OOD and DO.

(b) Proceed to scene and take charge of fire fighting action.

(c) Ensure that affected compartment is isolated.

(d) Call for emergency assistance as required.

(e) Evacuate all nonwatchstanding personnel unless required at the scene.

(f) Order EBS/OBA used as required.

(g) Keep maneuvering and control informed of status.

(3) OOD/DO

(a) Pass the word over the 1 MC and sound the general alarm.

(b) Order ship to minimum depth consistent with tactical situation.

(c) Order speed changed or maintained at 8 to 15 knots.

(d) Ensure all hands action is completed in accordance with general emergency and casualty control bill.

(e) Inform ships in the immediate vicinity as necessary.

(f) Shut outboard and inboard inductions and ventilation exhaust valves.

(g) Secure snorkeling if necessary.

(h) Be prepared to surface.

b. Alternate Action - If a fire occurs in the controls and monitoring circuits within the operation (control) room, or if control panels cannot be manned due to local fire conditions, it may be necessary to shift controls to local operating stations where possible.

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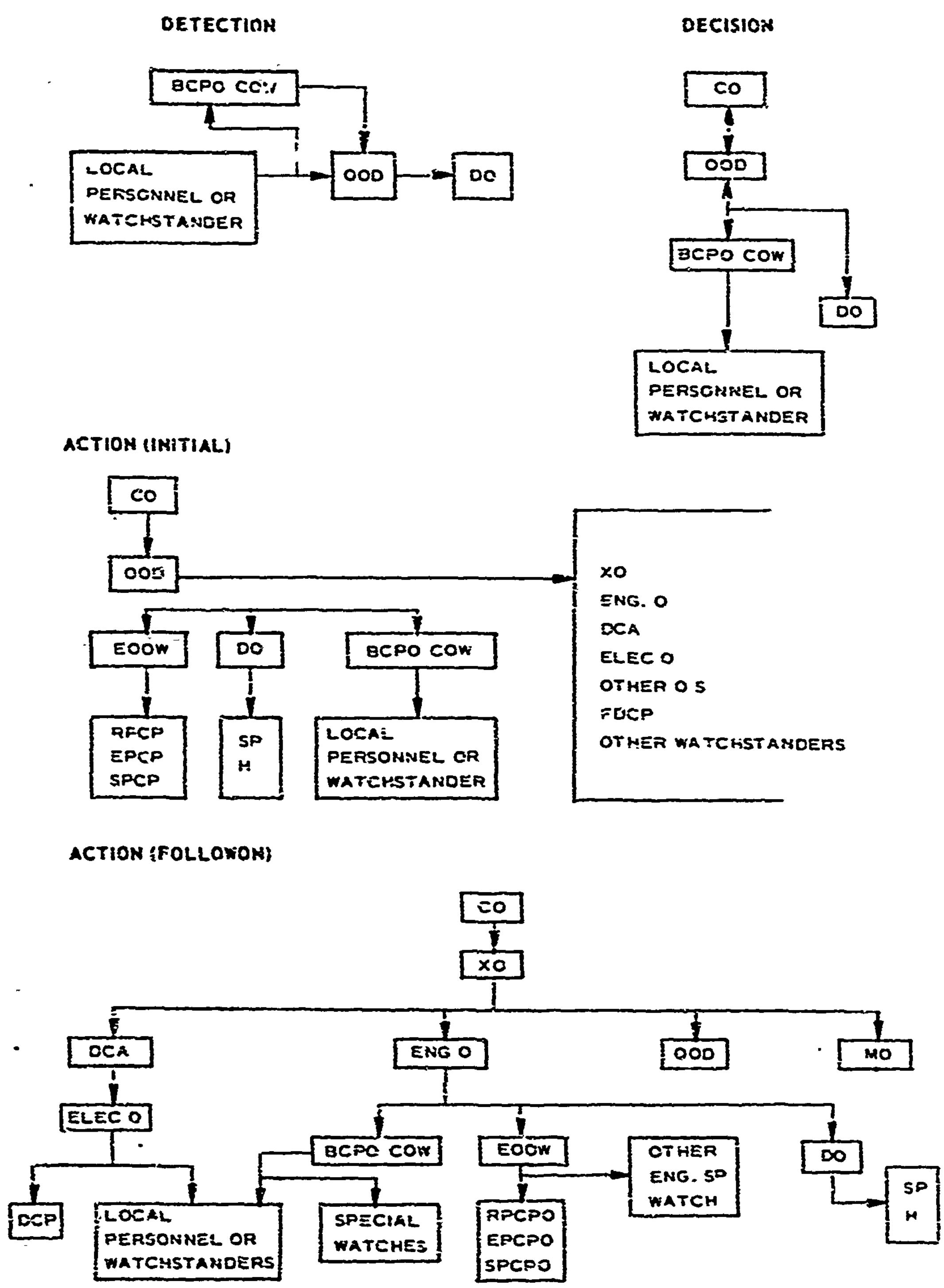
4. INFORMATION FLOW DIAGRAM



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5. FOLLOWON ACTION/FEEDBACK

a. Results - Indication of Results of Initial Action

(1) Local personnel observations are (1) status of fire; success in localization and control; (2) risk of fire spreading or reflashing; (2) completeness of electrical equipment isolation; (4) effects of damage and isolation on other systems; and (5) atmospheric contamination (smoke).

(2) Missile compartment/torpedo room watches are (1) reports of local personnel of 5a(1); and (2) effects on personnel.

(3) Control room includes (1) reports on local and missile compartment/torpedo room observation; and (2) ship status - depth, speed, and attitude.

b. Determine Supplement Actions Required - Same as 5a(2) and 5a(3).

c. Indication of Followon Results - Same as 5a.

d. Determine Action Required to Complete Recovery - Identify desired safe operating envelope and identify action required.

e. Complete Casualty Recovery

(1) Local personnel includes COW, OOD, DO, and damage control party, if required, to (1) inspect locus of fire to ensure material equipment is below the flash point; (2) commence emergency ventilation if required; (3) inspect secured equipment for damage and presence of combustible materials; (4) restore equipment to operation when safe to do so; and (5) lineup and secure fire fighting equipment upon orders from control restore normal ventilation.

(2) Control Room

(a) Order emergency ventilation of involved area, if required.

(b) Order fire fighting equipment and personnel protection equipment secured.

(c) Order depth, speed, trim, etc. to operate ship within safe operating envelope consistent with damage and tactical situation.

B - FIRE - AUXILIARY MACHINE ROOM NO. 1 AND 2 AND REACTOR COMPARTMENT

1. RECOGNITION

a. Initial Conditions - The submarine is assumed to be operating at

deep depth. Speed is 8 to 15 knots. Buoyancy is slightly positive.

b. Detection

(1) Detection of Impending Casualties

(a) Indicated or Felt High Temperature - Pump bearings, lube and hydraulic oil, hydraulic pumps, and control panels.

(b) Abnormal Operation of Equipment - Low fluid levels in heated tanks.

(c) Water Leakage or Flooding - Pump motors, control panels, power distribution boxes, panels or switchboards, and fans or heaters.

(2) Detection of Existing Casualties - Fire is detected visually and by smell by local personnel and watchstanders; for example, EOOW/EPOOW, auxiliary electrical aft; engine room supervisor. EOOW and OOD receive word via 4 MC.

c. Verification - Watchstanders make visual and tactual checks and EOOW will make confirmatory checks.

2. DECISION MAKING

a. Local Personnel

(1) Note location, specific equipment involved and type of fire.

(2) Note status and function of affected and adjacent equipment.

(3) Note rate of combustion and location of fire extinguishers.

(4) Recall available courses of action: (1) shut down affected and adjacent equipment; (2) request additional help; (3) use extinguisher agents: dry chemical, CO_2, high velocity fog, and water stream.

(5) Collate the information of 2a(1) and 2a(3) against alternatives of 2a(4).

(6) Select the course of action.

(7) OOD receives direction from EOOW/electrical officer and modifies or retains decision.

b. EOOW/Engineering Officer

(1) Note information of 2a(1) through 2a(3) and 2a(6) as reported by local personnel.

(2) Estimate effect of fire and local corrective action on propulsion, electrical, and hydraulic systems.

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(3) Estimate effect of fire and corrective action on ship's atmosphere.

(4) Assess status of ship systems.

(5) Recall available/mandatory courses of action: (1) supervisory functions; for example, ensure use of EBS/OBA; (2) evacuate compartment of nonwatchstanding personnel and/or all personnel; (3) isolate compartment - includes vent closure; (4) change lineup of equipment; and (5) measures to be taken for personnel protection.

c. OOD/DO

(1) Note current speed, depth, attitude, and trim.

(2) Assess crew capability, state of training, physiological/psychological condition, and reaction time.

(3) Assess status of essential ship's systems; for example, planes and rudder, hydraulics, propulsion, electrical, rig of oil systems, and rig of piping and ventilation system.

(4) Recall special instructions, ship's standing orders, and other constraints; for example, minimum depth, ice overhead, and surface ship activity.

(5) Recall available/mandatory courses of action; for example, change depth, change speed, rig for reduced electrical power, notify ships in vicinity, isolate ventilation systems, prepare for surfacing, and secure oxygen bleed.

(6) Evaluate courses of action taking into account seriousness of the fire and readiness to meet a subsequent casualty that may result from the fire.

(7) Select the course of action from 2c(5) and 2c(6).

(8) OOD receives information from EOOW and DO and direction from CO and XO. He may then be required to modify his decision.

3. CORRECTIVE ACTION

a. Basic Sequence

(1) Local Personnel

(a) Shut down affected and adjacent equipment where local control is feasible. Assistance is requested in securing equipment that is remotely controlled or not accessible because of the fire. Electrical equipment is isolated to the nearest accessible panel or switchboard.

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(b) For controllable electrical or oil fires that are accessible apply dry chemical fire extinguisher. If inaccessible, use the CO_2 extinguisher.

(c) If fire is not controllable by 3a(1)(b), request assistance and use the high pressure fog.

(d) If fire is, or becomes, large the EBS/OBA must be used.

(2) EOOW/Engineering Officer

(a) Pass the word via the 2 MC system to engineering compartment personnel.

(b) Proceed to scene and take charge of fire fighting action.

(c) Ensure that affected compartment is isolated.

(d) If pressurization of trim system is required, inform control prior to pressurizing the main. This will be necessary if fire is fought using water.

(e) Evacuate all nonwatchstanding personnel unless required at the scene.

(f) Order EBS/OBA used as required.

(g) Keep maneuvering and control informed of status.

(3) OOD/DO

(a) Pass the word via 1 MC system and sound the general alarm.

(b) Order ship to minimum depth consistent with the tactical situation.

(c) Order speed changed or maintained at 8 to 15 knots.

(d) Ensure that all-hands action is completed in accordance with general emergency and casualty con' ~ol bill.

(e) Inform ships in the immediate vicinity as necessary.

(f) Shut outboard and inboard induction and ventilation exhaust valves.

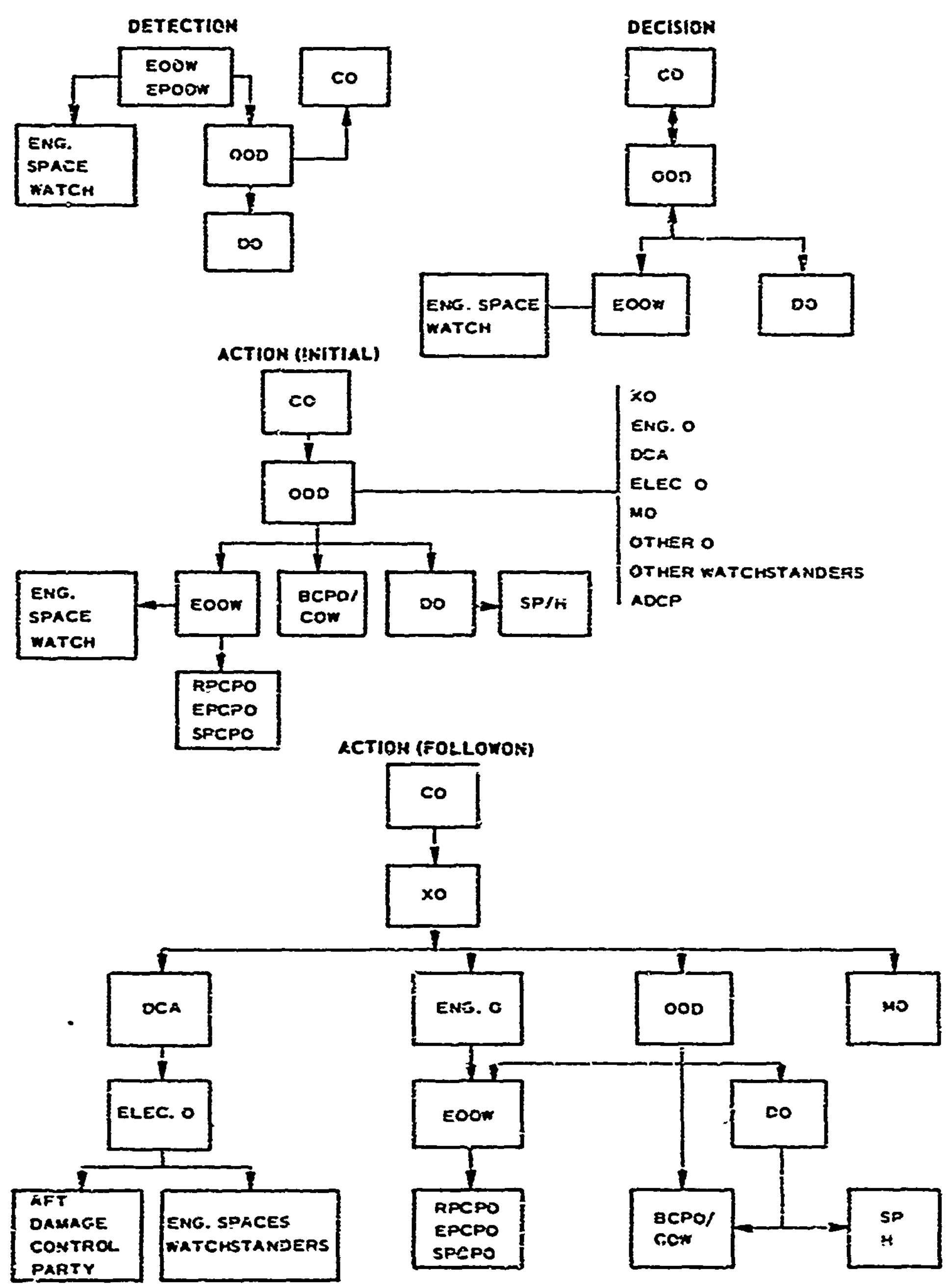
(g) If snorkeling, secure snorkeling.

(h) Be prepared to surface.

(i) Ensure that sound powered phones are manned and that proper use is being made of phone circuits.

b. Alternate Action - If fire occurs in the reactor compartment (the probability is rather low) it may be necessary and possibly advisable (due to the potential radiation) to let the fire burn itself out.

4. INFORMATION FLOW DIAGRAMS



5. FOLLOWON ACTION/FEEDBACK

a. Results - Indication of Results of Initial Action

(1) Local personnel (includes EOOW or electrical officer) observations.

(a) Status of fire: success in localization and control

(b) Risk of fire spreading or reflashing: presence of hydraulic fluid spillage/spray of lube oil

(c) Completeness of electrical equipment isolation

(d) Effects of damage and isolation on other systems

(e) Atmospheric contamination (smoke)

(2) Control Room

(a) Reports of local observations

(b) Ship status: depth, speed, attitude

b. Determine Supplemental Actions Required - Same as 5a(1) and 5a(2).

c. Indication of Followon Results - Same as 5a.

d. Determine Action Required to Complete Recovery - Identify desired safe operating envelope and identify action required.

e. Complete Casualty Recovery

(1) Local personnel (includes electrical officer and aft damage control party if required)

(a) Inspect locus of fire to ensure temperature of material and equipment is below flash point.

(b) Commence emergency ventilation if required.

(c) Inspect secured equipment for damage and presence of combustible materials.

(d) Restore equipment to operation when safe to do so.

(e) Upon orders from control, restore normal ventilation lineup and secure fire-fighting equipment.

(2) Control Room

(a) Order emergency ventilation of affected compartment, if required.

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(b) Order fire-fighting equipment and personnel protection equipment secured.

(c) Order depth, speed, trim, etc., to operate ship within a safe operating envelope consistent with damage and tactical situation

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C - FIRE - ENGINE ROOM

1. RECOGNITION

a. Initial Conditions - The submarine is assumed to be operating at deep depth. Speed is 8 to 15 knots. Buoyancy is slightly positive.

b. Detection

(1) Detection of Impending Casualties

(a) Indicated or Felt High Temperature - Pump bearings, overheated paint on steam lines, lube and hydraulic oil, and hydraulic pumps.

(b) Abnormal Operation of Equipment - Low fluid levels in heated tanks (main lube oil stowage, lube oil stowage settling, reserve hydraulic oil).

(c) Water Leakage or Flooding - Pump motors, control panels, SSTG's, ship-service load center, and electrical distribution panels.

(2) Detection of Existing Casualties

(a) Fire is detected visually and by smell by engine compartment watchstanders; for example, EOOW/EPOOW, SPCP, EPCPO, RPCPO, auxiliary electrical aft, engine room supervisor, ERUL watch, and ERLL watch.

(b) Alarms may be heard as

Low pressure - main lube oil, shaft lube oil, engine room ASW, and SSTG lube oil.

High temperature - main lube oil stowage (settling tank).

(c) EOOW and OOD will receive word via 4-MC system.

c. Verification - ERLL will make tactual checks of lube and hydraulic tanks that may emit smoke in ERLL and EOOW will make confirmatory checks.

2. DECISION MAKING

a. Local Personnel

(1) Note location, specific equipment involved, and type of fire.

(2) Note status and function of affected and adjacent equipment.

(3) Note rate of combustion and location of fire extinguishers.

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(4) Recall available courses of action.

(a) Shut down affected and adjacent equipment.

(b) Request additional help.

(c) Use extinguisher agents: dry chemical, CO_2, high velocity fog, water stream.

(5) Collate the information of 2a(1) through 2a(3) against alternatives of 2a(4).

(6) Select course of action.

(7) Receive direction from EOOW/electrical officer and modify or retain decision.

b. EOOW/Engineering Officer

(1) Note information of 2a(1) through 2a(2) and 2a(6) as reported by local personnel.

(2) Estimate effect of fire and local corrective action on propulsion, electrical, and hydraulic systems.

(3) Estimate effect of fire and corrective action on ship's atmosphere.

(4) Assess status of ship systems.

(5) Recall available/mandatory courses of action.

(a) Supervisory functions, for example, ensure use of EBS/OBA.

(b) Evacuate compartment of nonwatchstanding personnel and/or all personnel.

(c) Isolate compartment; includes vent closure.

(d) Change lineup of equipment.

(e) Sound power-plant emergency alarm.

(f) Determine means of personnel protection and system control if fire is in maneuvering room.

(g) General emergency actions; for example, secure battery charge, secure diesel engine, shut outboard and inboard, engine snorkel exhaust valves, and place a second SSMG and SSTG on the line and be ready to answer any bell on the main engines.

c. COD/DO

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(1) Note current speed, depth, attitude, and trim.

(2) Assess crew capability, state of training, physiological/psychological condition, and reaction time.

(3) Assess status of essential ship's systems, for example, planes and rudder, hydraulics, propulsion, electrical system, rig of oil systems, and rig of piping and ventilation systems.

(4) Recall special instructions, ship's standing orders and other constraints, for example, minimum depth, ice overhead, and surface ship activity.

(5) Recall available/mandatory courses of action, for example, change depth, change speed, rig for reduced electrical power, notify ships in vicinity, isolate ventilation systems, prepare for surfacing, and secure oxygen bleed.

(6) Evaluate courses of action, taking into account seriousness of the fire and readiness to meet a subsequent casualty that may result from the fire.

(7) Select the course of action from 2c(5) and 2c(6).

(8) OOD receives information from EOOW and DO and direction from CO and XO. He may then be required to modify his decision.

3. CORRECTIVE ACTION

a. Basic Sequence

(1) Local Personnel

(a) Shut down affected and adjacent equipment where local control is feasible. Request assistance in securing equipment that is remotely-controlled or not accessible because of the fire. Isolate electrical equipment at the nearest accessible panel or switchboard.

(b) For controllable electrical or oil fires that are accessible, apply dry chemical fire extinguisher. If inaccessible, use the CO_2 extinguisher.

(c) If fire is not controllable by 3a(1)(b), request assistance and use the high pressure fog.

(d) If fire is, or becomes, large the "BS/OBA must be used.

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(2) EOOW/Engineering Officer

(a) Pass the word via 2 MC to engineering compartment personnel.

(b) Proceed to scene and take charge of fire-fighting action.

(c) Ensure that affected compartment is isolated.

(d) Call for emergency assistance as required.

(e) Change power plant and electrical system linup to ensure most reliable operation.

(f) If pressurization of trim system is required, inform control prior to pressurizing the main. This will be necessary if fire is to be fought using water.

(g) Evacuate all nonwatchstanding personnel unless required at the scene.

(h) Order EBS/OBA manned as required.

(i) Answer engine bells.

(j) Keep maneuvering and control informed of status.

(3) OOD/DO

(a) Pass the word via 1 MC and sound the general alarm.

(b) Order ship to minimum depth consistent with the tactical situation.

(c) Order speed changed or maintained at 8 to 15 knots.

(d) Ensure all hands that action is completed in accordance with general emergency and casualty control bill.

(e) Inform ships in the immediate vicinity as necessary.

(f) Shut outboard and inboard induction and ventilation exhaust valves.

(g) If snorkeling, secure snorkeling.

(h) Be prepared to surface.

(i) Ensure that sound powered phones are manned and that proper use is being made of phone circuits.

b. Alternate Action - If a fire occurs in the control and monitoring circuits within the maneuvering room. (or control panels cannot be manned due to local fire conditions), it may be necessary to shift

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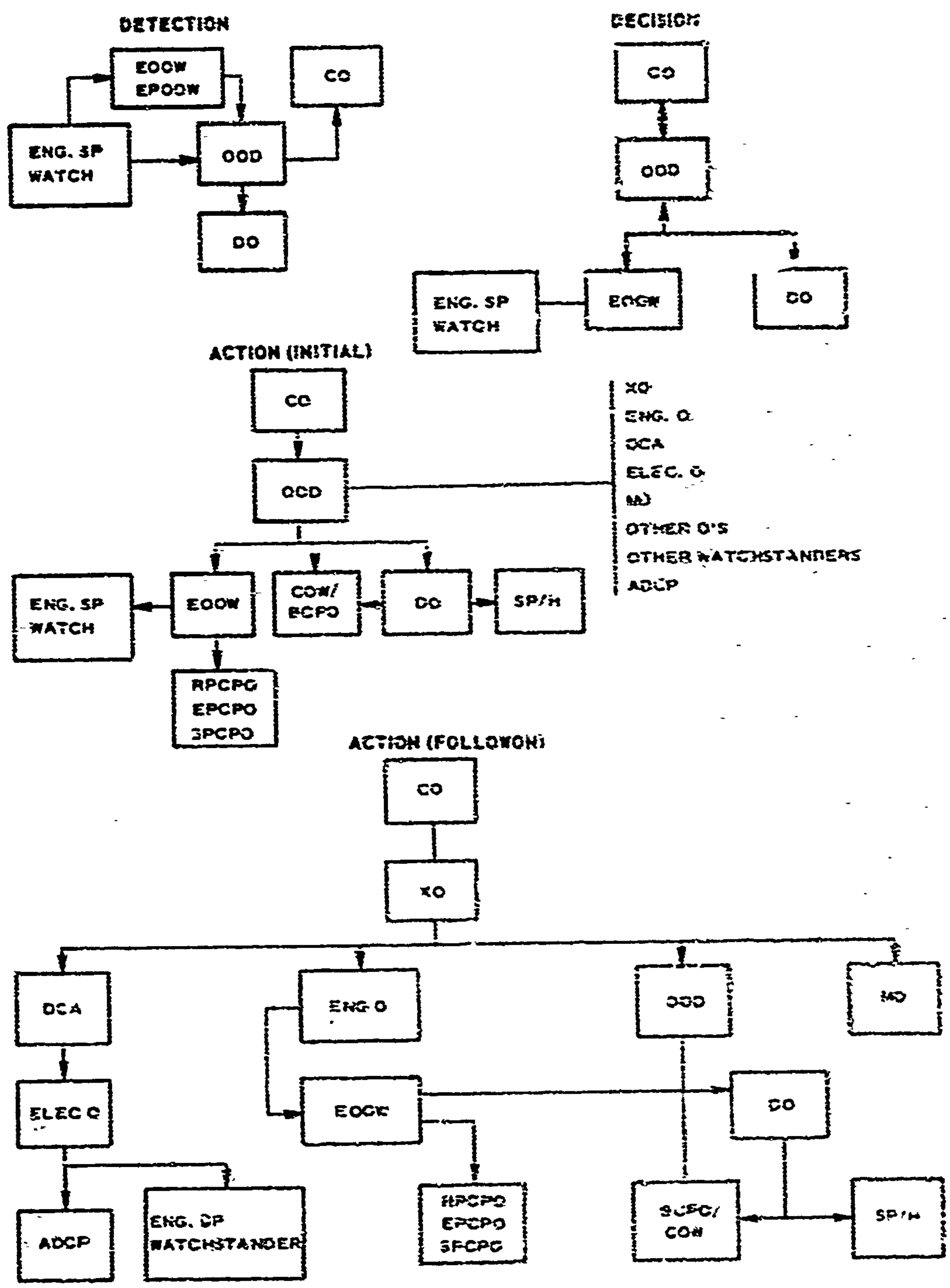
controls to local operating stations in the engine compartment. In such a case, additional qualified watchstanders will be required.

4. INFORMATION FLOW DIAGRAM



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5. FOLLOWON ACTION/FEEDBACK

a. Results - Indication of Results of Initial Action

(1) Local personnel (includes EOOW or electrical officer) observations.

(a) Status of fire: success in localization and control.

(b) Risk of fire spreading or reflashing: safety of pyrotechnic locker, adjacent hull insulation, presence of hydraulic fluid spillage or spray, or lube oil.

(c) Completeness of electrical equipment isolation.

(d) Effects of damage and isolation on other systems.

(e) Atmospheric contamination (smoke).

(2) Maneuvering Room Watch

(a) Report of local personnel observations of 5a(1).

(b) Status and lineup of propulsion, electrical, and hydraulic systems, for example, pressures and temperature of lube oil systems.

(c) Effects on personnel.

(3) Control Room

(a) Reports of Local and Maneuvering Room observations.

(b) Ship status: depth, speed, attitude.

b. Determine Supplemental Actions Required - Same as 5a(1) and 5a(2).

c. Indication of Followon Results - Same as 5a.

d. Determine Action Required to Complete Recovery - Identify desired safe operating envelope and identify action required.

e. Complete Casualty Recovery

(1) Local personnel (includes electrical officer and aft damage control party if required).

(a) Inspect locus of fire to ensure temperature of material and equipment is below the flash point.

(b) Commence emergency ventilation if required.

(c) Inspect secured equipment for damage and presence of combustible materials.

(d) Restore equipment to operation when safe to do so.

(e) Upon orders from control/MR restore normal ventilation lineup and secure fire-fighting equipment.

(2) Maneuvering Room (Engineering Offficer and EOOW)

(a) Report status of fire and essential ship systems to control.

(b) Direct local personnel to restore equipment to operation as appropriate.

(c) Supervise cleanup of combustible and fire extinguisher material.

(d) Stand prepared to operate the ship ventilation system as directed by the CO/XO/OOD.

(3) Control Room

(a) Order emergency ventilation of engine compartment, if required.

(b) Order fire-fighting equipment and personnel protection equipment secured.

(c) Order depth, speed, trim, etc. to operate ship within a safe operating envelope consistent with damage and tactical situation.

D - FLOODING - BOW COMPARTMENT

1. RECOGNITION

a. Initial Conditions - The submarine is assumed to be operating at deep depth. Speed is 8 to 15 knots. Buoyancy is slightly positive. Basic variables relevant to detection of a casualty consist of ordered attitude and trim and rig status.

b. Detection

(1) Detection of Impending Casualties

Watchstanders torpedo room watch (TRW) note leakage. Control room notes a change in trim heavy forward (applies only when watchstanders fail to detect leakage.)

(2) Detection of Existing Casualties

Watchstanders detect and report to control the location and rate (moderate, severe, or extreme) of flooding. Symptoms detectable by watchstanders may consist of one or more of the following:

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(1) increasing water level in compartment, (2) water on the bulkhead and/or overhead, (3) sound and/or sight of a rushing stream or jet of water, and (4) appearance of high pressure fog or water vapor.

c. Verification - In ambiguous cases of flooding, the watchstander on the scene will attempt to check his initial impression. EEOW or EPOOW may check the space to verify rate and location. Watchstanders at adjacent stations check and report conditions.

2. DECISION MAKING

a. OOD/CO

(1) Ship Characteristics - Speed, depth, attitude, trim/buoyancy, rig status, reported nature, and location of flooding are noted.

(2) Crew Characteristics - Crew capability, state of training, physiological/psychological condition and reaction time are assessed.

(3) System Status - Status of following essential ship systems is assessed:

1. Essential systems for recovery, for example, propulsion, hydraulic system, MBT blow system, variable ballast system, air bank pressure/capacity, and communications.
2. Possible system degeneration due to flooding. If bow compartment is completely flooded at deep depth, WT bulkhead (frame No. 31) may collapse and result in flooding of operations compartment, missile compartment, and engineering spaces aft. Spaces and equipment that may be flooded include the crew's living space, battery space, missile control equipment air-conditioning, missile control center, and missile compartment.

(4) Potential Sources of Flooding

(a) Torpedo tubes (4) - 21 in.

(b) Muzzle and breech doors

(c) Ammo locker, pyrotechnic locker and torpedo tube flood, hull, and backup valves - 1 in.

(d) Forward signal ejector hull and backup valves - 1/2 in.

(e) Forward signal ejector muzzle valve and breech door - 3 in.

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(f) Escape and torpedo loading trunk

(g) MBT vent valves

(h) Flood and drain torpedo tube backup valves (4) - 5 in.

(5) Estimate seriousness of flooding.

(6) Recall special instructions, ship's standing orders and other constraints; for example, minimum depth, ice overhead, and surface ship activity.

(7) Recall available courses of action, for example, blow forward MBT's, blow all MBT's, emergency blow, plane up to shallower depth, engine ahead full, engine ahead flank, and engine moderate speed.

(8) Select the course of action from 2a(7).

b. Local Personnel (Including Watchstanders)

(1) Determine what assistance is needed.

(2) Determine what immediate local action can be taken to stop the flooding including isolation and emergency damage control. Consideration will be given to such factors as accessibility to valves or remote controls and availability of suitable damage control materials.

(3) Make decisions relative to evacuation and isolation of the compartment.

3. CORRECTIVE ACTION

a. Basic Sequence (Deep Submergence)

(1) OOD/CO

(a) Pass the word to all hands (collision alarm)

(b) Emergency/blow MBT's

(c) Ship's speed of at least AHEAD 2/3.

(d) Attempt to maintain ship's angle of UP 30 deg.

(e) Sound collision alarm.

(f) Pump forward variable ballast tanks.

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(2) Watchstanders (and/or local personnel)

(a) Make initial report to control giving nature, location, and system affected.

(b) Shut valves or doors if feasible (activate remote control for all torpedo room valves and muzzle doors).

(c) Dog WT door separating bow from operations compartment.

(d) Other watchstanders must close all WT doors, shut all bulkhead flappers, and secure compartment recirculation blowers and precipitrons.

(3) EOOW

(a) Ensure that WT doors are closed and dogged, bulkhead flappers are shut, and compartment recirculation blowers and precipitrons are secured.

(b) If applicable, secure the battery charge, secure the diesel engine, and shut the outboard and inboard engine snorkel exhaust valves.

(c) Place the second MG and TG on the line.

(d) Change powerplant and electrical system lineup to ensure most reliable operation.

(e) Prepare to answer speed bells within power plant limitations.

b. Representative Alternative Actions - If the ship is above the collapse depth of bulkhead No. 31 and the compartment is isolated, the OOD may choose to blow the forward MBT's and plane up to a depth where the bow compartment can be pressurized to stop the flooding.

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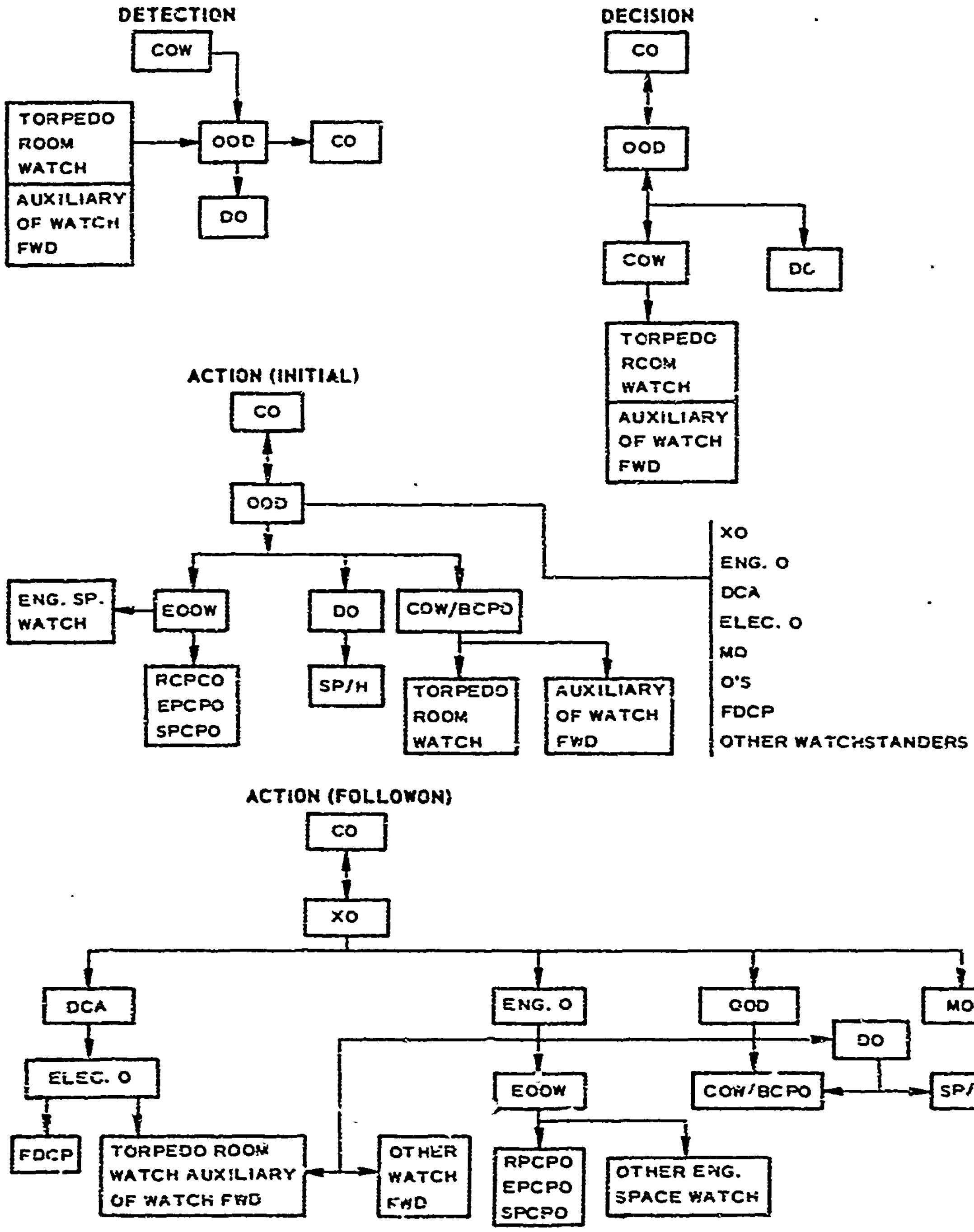
4. INFORMATION FLOW DIAGRAM



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5. FOLLOWON ACTION/FEEDBACK

a. Results - Indication of Results of Initial Action

(1) The CO/OOD/DO makes observations of the ship's response, including the ship's angle, depth change rate, depth, speed, air bank pressure, and roll and turbulence.

(2) Watchstanders and local personnel report the location of flooding if identifiable, flooding rate, action and scucess in isolating the flooding, effect of flooding in other components, and amount of water taken aboard.

(3) EOWW/EPOOW reports any changes in status of essential ship systems.

b. Determine Supplemental Actions Required

(1) CO/OOD/DO

(a) Adjusts plane angles.

(b) Adjusts blow - If emergency blow has not been previously ordered and ship is responding unsatisfactorily, emergency blow is ordered. If ship instability is too great with emergency blow, normal blow is initiated.

(c) Order compartment bilges pumped if consistent with tactical situation. CO/OOD may also compensate for flooding by pumping from variable ballast tanks.

(2) Local Personnel - Commence emergency measures to stop or retard flooding within their capabilities. Continue attempt to isolate flooding as accessibility is improved by reduced impingement, etc. when depth is reduced.

(3) EOOW/EPOOW

(a) Ensure bells are answered as directed and within the capability of the propulsion plant.

(b) Continue lineup of power plant for most reliable operation.

(c) Prepare lineup for compartment dewatering.

c. Indication of Followon Results

(1) Ship Status - Followon conditions of basic recovery procedure are decreasing depth (stable rate), maintainable up angle ≅ 30 deg, ahead speed ≅ 5 knots, depth approaching ≅ 150 ft, reserve air bank pressure, flooding confined to affected compartment, flooding

rate reduced, and excessive roll and turbulence may be experienced.

(2) Watchstanders/Local Personnel

(a) Offwatch personnel arrive at stations in accordance with General Emergency and Damage Control Bill.

(b) Electrical Officer takes charge at the scene.

(c) Information of 5a(1) is updated.

(3) Engineering Officer/EOOW

(a) Engineering Officer arrives at station and assumes supervisory responsibility.

(b) Information of 5a(2) is updated.

(4) Followon conditions of alternate recovery procedure is the same as 5, c, (1) except that the excessive roll and turbulence associated with emergency MBT may not be experienced.

d. Determine Action Required to Complete Recovery - Desired (safe) operating envelope and action required using information of 5c are identified.

e. Complete Casualty Recovery

(1) Representative action for completion of recovery procedure.

(a) Secure MBT Blow.

(b) If ascent continues at approximately the same rate and angle remains controllable, decrease up angle to level off at desired depth.

(c) If depth can be maintained with slight down angle, adjust speed to between 5 and 10 knots and cycle vents (forward-aft).

(d) Take appropriate action to secure or compensate for flooding. Alternatives include pressurizing the bow compartment, pumping the bilges, and if a problem of impingement exists to prevent access to control valves at deep depth and is subsequently reduced, close valves.

E - FLOODING: OPERATIONS OR MISSILE COMPARTMENT

1. RECOGNITION

a. Initial Conditions - The submarine is assumed to be operating at deep depth. Speed is 8 to 15 knots. Buoyancy is slightly positive.

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Basic variables sometimes relevant to detection of a casualty consist of ordered attitude and trim and rig status.

b. Detection

(1) Detection of Impending Casualties - Control room notes a change in trim if watchstanders or local personnel fail to detect leakage. Following watchstanders or local personnel note leakage:

1. Ship control watches at control room, attack center, navigation center, and sonar room
2. Weapons watches at missile control center and missile compartment
3. Auxiliary electrical foward watches
4. Auxiliary men forward watches
5. Special watches; for example, Galley, Ship's Office, and Supply
6. Other local personnel at crew's living space, officer's living space, and CPO's living space

(2) Detection of Existing Casualties - Watchstanders detect and report to control the location and rate of flooding. Weapons watch will also report to the missile control center.

Symptoms detectable by watchstanders may consist of one or more of the following: (1) rapidly increasing water level in the compartment or bilges, (2) water on the bulkhead and/or overhead, (3) sound and/or sight of a rushing stream or jet of water, and (4) appearance of high-pressure fog or water vapor.

c. Verification - In ambiguous cases of flooding, the watchstander on the scene will attempt to check his initial impression. EOOW or EPOOW may check the space for purposes of verifying rate and location. Watchstanders at adjacent stations will check and report conditions.

2. DECISION MAKING

a. CO/OOD

(1) Ship Characteristics - Note speed, depth, attitude, trim/buoyancy, rig status, reported nature, and location of flooding.

(2) Crew Characteristics - Assess crew capability, state of training, physiological/psychological condition, and reaction time.

(3) System Status - Assess status of essential ship systems.

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(a) Essential systems for recovery, for example, propulsion, hydraulic system, MBT blow system, and communications.

(b) Possible degradation of essential systems due to flooding of the battery, fairwater plane positioning equipment, battery switchboards, ballast blow and vent control panel, electronic equipment space, MK-19 gyro control, 400-cps switchboard, sonar equipment, communications equipment, IC switchboard, ballast control panel, steering and diving station, underwater telephone, and ventilation control.

(4) Potential Sources of Flooding

(a) Hull penetrations that may be open while submerged below periscope depth are listed below:

AN/BRA-9 leakoff hull valve	1/4 in.
VLF loop antenna leakoff hull valve	1/4 in.
Type 11 fair leakoff hull valve	1/4 in.
Snorkel mast leakoff hull valve	1/4 in.
AN/BRA-15 leakoff hull valve	1/4 in.
Transit mast leakoff hull valve	1/4 in.
IFF/UHF antenna leakoff hull valve	1/4 in.
Bridge access trunk drain hull valve	1/4 in.
No. 1 periscope leakoff hull valve	1/4 in.
No. 2 periscope leakoff hull valve	1/4 in.
AN/BPS-11 mast leakoff hull valve	1/4 in.

(b) Crew's living space

Depth gage sea pressure Sensing (hull and backup) (2)	1/2 in.
Sanitation tank No. 1 overboard discharge (hull and backup)	3 in.
TDU (trash disposal unit, hull and backup)	10 in.

(c) Ship control center

Indicator mast drain and 20 psig air (hull and backup)	1/2 in.
ECM/DF mast backoff (hull)	1/2 in.
Type 11 heat exchanger SW outlet (hull and backup)	1-1/2 in.

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Type 11 heat exchanger SW inlet (hull and backup)	1-1/2 in.
Md mast drain (hull and backup)	1-1/2 in.

(d) Missile Compartment

Missile tube outboard vent (hull and backup)	1-1/2 in.
SW headers overboard (hull and backup)	1-1/2 in.
Sanitation tank No. 4 overboard discharge (hull and backup)	2 in.
Depth detector sea pressure sensing (2)	1/2 in.
Underwater log (2) (flapper)	6 in.
Missile tube No. 2 compensating	7 in.

(e) Missile Tubes

Missile tube No. 4 compensating (hull valve)	7 in.
Missile tube No. 6 compensating (hull valve)	7 in.
Missile tube No. 8 compensating (hull valve)	7 in.
Missile tube No. 10 compensating (hull valve)	7 in.
Missile tube No. 12 compensating (hull valve)	7 in.
Missile tube No. 14 compensating (hull valve)	7 in.
Missile tube No. 16 compensating (hull valve)	7 in.
Missile tube No. 1 compensating (hull valve)	7 in.
Missile tube No. 3 compensating (hull valve)	7 in.
Missile tube No. 5 compensating (hull valve)	7 in.
Missile tube No. 7 compensating (hull valve)	7 in.
Missile tube No. 9 compensating (hull valve)	7 in.

Missile tube No. 11 compensating (hull valve) 7 in.

Missile tube No. 13 compensating (hull valve) 7 in.

Missile tube No. 15 compensating (hull valve) 7 in.

Horizontal system sea-pressure sensing

Hull and backup 1/2 in.

Other sources of leakage or flooding, bridge access hatch, masts and periscope, missile hatches, and trash ejection unit.

(5) Estimate seriousness of flooding.

(6) Recall special instructions, ship's standing orders, and other constraints, for example, minimum depth, ice overhead, and surface ship activity.

(7) Recall available courses of action, for example, plane up to shallower depth, engine ahead full or ahead flank, engine, moderate speed, blow MBT, and emergency blow MBT.

(8) Select the course of action from 2a(7) considering the information of 2a(1) through 2a(6).

b. Local Personnel (Including Watchstanders)

(1) Determine assistance needed.

(2) Determine what immediate local action can be taken to stop the flooding, including isolation and emergency damage control; consideration will be given to such factors as accessibility to valves or remote controls and to the availability of suitable damage control materials.

(3) Make decisions relative to evacuation and isolation of the compartments.

3. CORRECTIVE ACTION

a. Basic Sequence (Deep Submergence)

(1) OOD/CO

(a) Pass the word to all hands.

(b) Emergency blow MBT's.

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(c) Ship's speed of at least ahead 2/3.

(d) Attempt to maintain ship's angle of up 30 deg.

(e) Sound collision alarm.

(f) Pump variable ballast tank.

(2) Watchstanders (and/or local personnel)

(a) Make initial report to Control, giving nature, location and system affected.

(b) Shut valves or doors if feasible.

(c) Close and dog all WT doors, shut all bulkhead flappers, secure compartment recirculation blowers, and precipitrons.

(3) EOOW

(a) Ensure that WT doors are closed and dogged, bulkhead flappers are shut, and compartment recirculation blowers and precipitrons are secured.

(b) If applicable, secure the battery charge, secure the diesel engine, and shut the outboard and inboard engine snorkel exhaust valves.

(c) Place the second MG and TG on the line.

(d) Change powerplant and electrical system lineup to ensure most reliable operation.

(e) Prepare to answer speed bells within powerplant limitations.

(4) Missile Control Center/Launch Control Station

(a) Check ordnance devices safed.

(b) Isolate electrical control equipment that may be affected by flooding.

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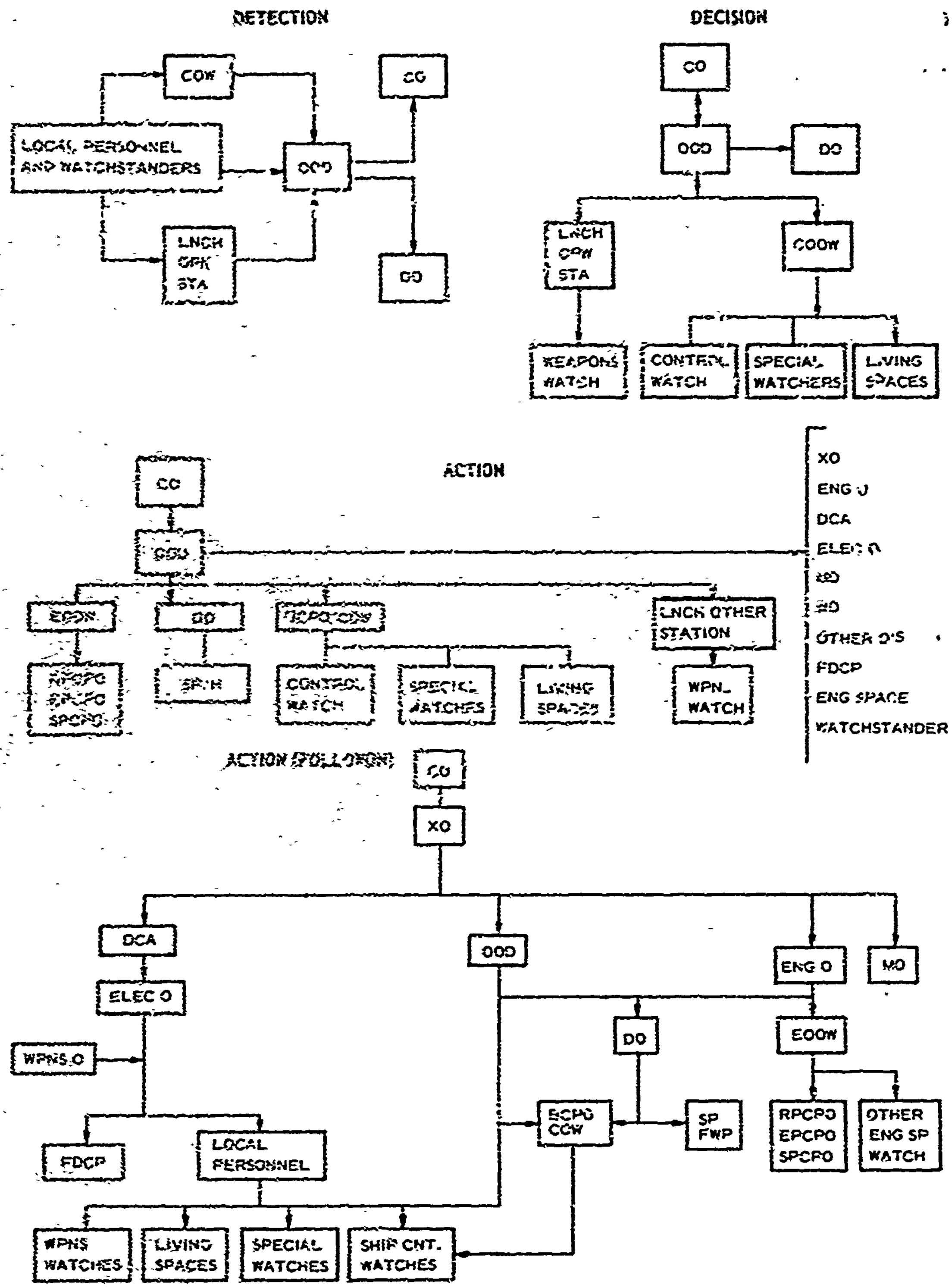
4. INFORMATION FLOW DIAGRAM



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5. FOLLOWON ACTION/FEEDBACK

a. Results - Indication of Results of Initial Action

(1) The CO/OOD/DO make observations of the ship's response, including the ship's angle, depth, and depth change rate, speed, air bank pressure, and roll and turbulence.

(2) Watchstanders and local personnel report the location of flooding if identifiable, flooding rate, action, and success in isolating the flooding, effect of flooding in other compartments, and amount of water taken aboard.

(3) EOOW/EPOOW reports any changes in status of essential ship stations.

(4) Missile Control Center/Launch Control Center reports hazardous conditions involving the ordnance.

b. Determine Supplemental Actions Required

(1) CO/OOD/DO

(a) Adjusts plane angles

(b) Adjusts blow

(c) If emergency blow has not been previously ordered and ship is responding unsatisfactorily, orders emergency blow.

(d) If ship instability is too great with emergency blow, change to normal MBT blow.

(e) Orders compartment bilges pumped if consistent with tactical situation; CO/OOD may also compensate for flooding by pumping from variable ballast tanks.

(2) Local Personnel

(a) Commence emergency measures to stop or retard flooding within their capabilities. Continue attempts to isolate flooding as accessibility is improved by reduced impingement, etc. when depth is reduced.

(b) Evacuate nonessential personnel.

(3) EOOW/EPOOW

(a) Ensure bells are asnwered as directed and within the capability of the propulsion plant.

(b) Continue lineup of power plant for most reliable operation.

(c) Prepare lineup for compartment dewatering.

c. Indication of Followon Results

(1) Ship Status - Followon conditions of basic recovery procedure are decreasing depth, maintainable up angle = 30 deg, ahead speed = 5 knots, depth approaching = 150 ft, reserve air bank pressure, flooding confined to affected compartment, flooding rate reduced, and excessive roll and turbulence may be experienced.

(2) Watchstanders/Local Personnel

(a) Off-watch personnel arrive at stations in accordance with General Emergency and Damage Control Bill.

(b) Electrical Officer takes charge at the scene.

(c) Information of 5a(1) is updated.

(3) Engineering Officer/EOOW

(a) Engineering Officer arrives at station and assumes supervisory responsibility.

(b) Information of 5a(2) is updated.

(4) Followon conditions of alternate recovery procedure are the same as 5c(1) except that the excessive roll and turbulence associated with emergency MBT blow may not be experienced.

d. Determine Action Required To Complete Recovery - Identify desired (safe) operating envelope and identify action required, using information of 5c.

e. Complete Casualty Recovery

(1) Secure MBT Blow

(2) If ascent continues at approximately the same rate and the angle remains controllable, decrease the up angle to level ship off at desired depth.

(3) If depth can be maintained with slight down angle, adjust speed to between 5 and 10 knots and cycle vents (forward-aft).

(4) Take appropriate action to secure or compensate for flooding. Alternatives include pressurizing the flooded compartment, pumping the bilges, and if a problem of impingement existed to prevent access to control valves at deep depth and is subsequently reduced, closing valves.

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F - FLOODING: ENGINE ROOM OR AMR NO. 2

1. RECOGNITION

a. Initial Conditions - The submarine is assumed to be operating at deep depth. Speed is 8 to 15 knots. Buoyancy is slightly positive. Basic variables sometimes relevant to detection of a casualty consist of ordered attitude and trim and rig status. Other important variables include the following. Equipment in operation, for example, ASW, MSW, refrigeration, freon air-conditioning, lithium bromide air-conditioning, signal ejector, distilling units (2000 + 8000 GPD), diesel generator set, MG sets, trim pump, and drain pump.

b. Detection

(1) Detection of Impending Casualties

(a) Engineering space watchstanders note leakage;that is, rising water in bilges, dripping from bulkheads or overheads, small streams of water without force.

(b) Control room watchstanders note a change in trim " heavy aft. " (Applies only when engineering space watchstanders fail to detect leakage.)

(2) Detection of Existing Casualties

(a) Engineering space watchstanders detect and report to MR/Control the location and rate (moderate, severe, or extreme) of flooding.

(b) Symptoms detectable by watchstanders may consist of one or more of the following: (1) abnormal increase in bilge level, (2) water on the bulkhead and/or overhead, (3) sound and/or sight of a rushing stream or jet of water, and (4) appearance of high-pressure fog or water vapor

(c) The nature of flooding, although not yet scaled in terms of objective measurements or observations, is directly related to rate, depth, location, equipment affected, and type (sea water or fresh water).

(3) Verification - In ambiguous cases of flooding, the watchstander on the scene will attempt to check his initial impression. EOOW or EPOOW may check the space to verify rate and location. Watchstanders at adjacent stations will check and report conditions.

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2. DECISION MAKING

a. OOD/CO

(1) Ship Characteristics - Note speed, depth, attitude, trim/buoyancy, rig status, reported nature, and location of flooding.

(2) Crew Characteristics - Assess crew capability, state of training, physiological/psychological conditions, and reaction time. The EOOW will be given special consideration.

(3) System Status - Assess status of essential ship systems.

(a) Essential systems for recovery, for example, propulsion (main engine system), steam system, electrical power, electrical control, especially reactor control system, hydraulic system, MBT blow system, variable ballast system, communications, air bank pressure/capacity, and drain pump.

(b) Flooding Degradation - Possible system degradation due to flooding is as follows:

1. ERUL - flooding aft

   Hydraulic plants - may lose normal plane power should hydraulic plants fail due to fire.

   May lose main and shaft lube oil pumps in ERLL.

   May lose propulsion and SSTG's through loss of vacuum and overheating of lube oil due to isolation of ASW aft.

2. ERUL - flooding forward

   May lose air-conditioning.

   SSTG may become airbound.

3. ERLL - flooding aft

   May lose aft ASW system.

   May lose main and shaft lube oil pumps and eventually lose propulsion.

4. ERLL - flooding forward

   May lose drain pump.

   May lose air-conditioning.

   Would lose propulsion and SSTG's if opening occurs in MSW system.

5. No. 2 AMRUL - aft and forward

   May lose SSMG after a time delay.

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May lose 2S and 6S switchboards that control MG, TG, diesel generator, and main coolant pumps.

May lose power supplies and control panels for PRIMARY and STEAM power plant systems.

May lose trim pump control.

6. No. 2 AMRLL

May lose CO_2 scrubber, CO and H_2 burner, amine tank, 300-kw MG set, diesel generator, RPFW pumps, ASW pumps, coolant charging and booster pumps and charging/discharge station, and main feed pumps.

(c) Flooding versus bulkhead strength - The engineering compartment/AMR No. 2 bulkhead is a high-pressure salvage bulkhead. Above bulkhead test depth, this bulkhead will provide the following: if flooding is forward of the engine room, it will permit personnel escape from the after escape trunk; it will permit use of the after signal ejector; it will permit operation of the propulsion plant as long as vital auxiliaries and reactor control equipment in AMR No. 2 are not rendered inoperable.

If flooding is in the engine room, the bulkhead will prevent flooding in compartments forward of the engine room, which will permit certain electrical equipment to be operated, such as lighting and underwater telephone and escape through the torpedo room escape trunk. It will also avoid other hazards such as fire and atmosphere contamination forward of the bulkhead.

The test depth of other bulkheads except the bow/operations compartment bulkhead is only 300 ft. Thus, the capability of preventing AMR No. 2 flooding from spreading forward is much less than in the case of engine room flooding.

(4) Potential Sources of Flooding

(a) ERUL - aft port

Hull penetrations - signal ejector flooding (overhead), 1/2 in.; overboard shaft seal (centerline), 3/4 in.; signal ejector (616) class, 3 in.

Internal systems - 2000-lb distilling plant

(b) ERUL - aft starboard

Hull penetrations - stern tube and cooling (centerline), 1/2 in.; engine room overboard discharge (overhead), 4 in.

Internal systems - HP air compressor, shaft seal system

(c) ERUL - forward port

Hull penetrations - SW overboard discharge (overhead), 6 in.

Internal systems - air ejector condenser, 8000-gal distillery, lithium bromide air-conditioning plant, continuous vent connections for No. 2 SSTG

(d) ERUL - forward starboard

Hull penetrations - SW overboard discharge (overhead), 6 in.

Internal systems - air ejector condenser, continuous vent for No. 1 SSTG

(e) ERLL - aft port

Hull penetrations - engine room ASW suction (deckplate), 4 in.

Internal systems - ASW pumps, HP air compressor, bilge wells

(f) ERLL - aft starboard

Hull penetrations - none

Internal systems - lube oil coolers, bilge wells

(g) ERLL - forward port

Hull penetrations - drain pump overboard discharge, 3 in.; air-conditioner salt water suction (bilges), 8 in.; MSW overboard discharge (2 to 3 ft outboard), 14 in.; No. 2 MSW suction (deck plate), 14 in.

Internal systems - drain system, HP brine pump, MSW, air-conditioner ASW pumps, drain pumps, SSTG lube oil coolers, bilge wells

(h) ERLL - forward starboard

Hull penetrations - refrigeration air-conditioning overboard discharge (above deck plate), 5 in.; AC suction (bilges), 8 in.; MSW overboard disk (2 to 3 ft outboard of condenser), 14 in.; No. 1 MSW suction (deck plate level), 14 in.

Internal systems - air-conditioning, MSW, SSTG lube oil coolers, continuous vent systems, bilge wells

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(i) No. 2 AMRUL - aft port

Hull penetrations - SSMG air-cooler overboard discharge (overhead), 2-1/2 in.

Internal systems - SSMG air-cooler

(j) No. 2 AMRUL - aft starboard

Hull penetrations - none

Internal systems - none

(k) No. 2 AMRUL - forward port

Hull penetrations - diesel exhaust outboard vent, 1/2 in.; diesel exhaust outboard exhaust valve drain, 1/2 in.; main steam relief valve overboard discharge, 2 in.;

Internal systems - none

(l) No. 2 AMRUL - forward starboard

Hull penetrations - diesel SW overboard discharge (overhead), 3 in.; diesel exhaust vent (2 to 6 ft), 1/2 in.; reactor FW/SW cooler SW overboard discharge (Nr. overhead), 4 in.; diesel exhaust drain (2 to 6 ft), 1/2 in.; main steam relief valve overboard discharge (deck plate), 2 in.

Internal systems - reactor FW/SW coolers

(m) No. 2 AMRLL - aft port

Hull penetrations - sanitary tank overboard discharge (bilges), 2 in.; AMR No. 2 ASW pump No. 1 suction, 6 in.; AMR No. 2 ASW pump No. 2 suction, 6 in.

Internal systems - SSMG cooling system, bilge well

(n) No. 2 AMRLL - aft starboard

Hull penetrations - trim system suction and overboard discharge (deck plate), 5 in.

Internal systems - trim system, SSMG cooling, bilge well

(o) No. 2 AMRLL - forward port

Hull penetrations - reactor coolant overboard discharge (deck plate), 2 in.

Internal systems - CO_2 scrubber, ASW pumps, bilge wells

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(p) No. 2 AMRLL - forward starboard

Hull penetrations - steam generator blow overboard discharge (below deck plate), 1-1/2 in.

Internal systems - CO_2 scrubber, diesel generator, bilge wells

(5) Recall special instructions, ship's standing orders, and other constraints, for example, minimum depth, ice overhead, and surface ship activity.

(6) Recall available courses of action, for example, plane up to shallower depth, engines full speed, blow MBT, emergency blow MBT, engine moderate speed - main coolant pumps slow and MBT blow, backing down, use of trim pump and none.

b. EOOW

(1) Verify location and rate of flooding; determine specific source of flooding.

(2) Assist engine watchstanders.

(3) Review status of essential equipment in the engineering compartments and possible effects of flooding.

(4) Recall rig status of sea water systems.

(5) Recall alternate courses of corrective action.

(a) Compartment isolation.

(b) Sea water piping isolation or alternate rigging for flow reduction.

(c) Protection of essential equipment in engineering compartment.

(d) Equipment operation and processes to be secured.

(e) Powerplant capabilities under degraded conditions, for example, reduced or stopped main salt water coolant system.

(f) Arrangement for backup of equipment essential to recovery.

(6) Collate the information of 2b(1) through 2b(4) against 2b(5).

(7) Prepare a tentative plan of action.

(8) Revise plan of action to be compatible with OOD direction.

3. CORRECTIVE ACTION

a. Basic Sequence

(1) CO/OOD/DO

(a) Emergency blow of all MBT's if one or more of the following occurs - propulsion is lost, propulsion is capable of low speed only, the ship is at deep depth, an appreciable quantity of water has been or is being taken aboard, and ship control is threatened.

(b) Ship's speed of at least ahead 2/3.

(c) Attempt to maintain ship's angle of up 30 deg; secure AMC.

(d) Pass the word and sound the collision alarm.

(e) Pump variable ballast tank.

(2) Watchstanders (and/or Local Personnel) Engine Compartment and No. 2 AMR

(a) Make initial report via 4 MC to Control and Maneuvering on the nature, location, and system affected, if known.

(b) Isolate component/system from which flooding occurs if identifiable and if valves are locally controllable and accessible. Otherwise, proceed as follows - shut all ASW hull and backup valves, shut all ASW and MSW hydraulically operated continuous vent valves, stop ASW pumps in affected compartment, shut associated hull and backup valves from auxiliary sea systems, and dog WT doors and secure all bulkhead penetrations in affected compartment.

(c) Report action and results to maneuvering room.

(3) EOOW/EPOOW

(a) Ensure action of 3a(2) is taken. Supplement such action by remote closure of ASW hull stop valves.

(b) If flooding is from MSW loop, affected side is identified and the following is accomplished - shut MSW hull, backup and cross-connect valves, secure MSW pump, if closed for checking, reopen MSW hull and backup valves on unaffected side, secure main engine steam flow, shift SSTG loads to unaffected side, secure steam to affected SSTG, and secure affected air ejector.

(c) Checks and/or switches - main coolant system to slow. Answers speed bells within powerplant limitations.

(d) If applicable, secure battery charge, diesel generator, and outboard and inboard engine snorkel exhaust valves.

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b. Representative Alternate Actions

(1) If the source of water influx can be isolated immediately, or if rate is low and if propulsion system, electrical and reactor control systems, and ship control system are not affected, then the OOD may choose not to blow the MBT's and instead will plane up to a safer depth. Action will be taken as follows:

1. OOD

Passes the word to all hands over 1 MC.

Orders speed AHEAD full.

Orders change to shallower depth consistent with tactical situation.

Diving officer maintains an UP angle of up to 30 deg.

Sounds collision alarm

2. EOOW/EPOOW

Prepares the power plant for maximum propulsion and electrical capability consistent with safety and reliability

Passes the word via 2 MC to engineering compartment watchstanders

Takes charge at the scene of casualty

Ensures appropriate actions of 3a(3) above are taken; for example, closure of suction, discharge and continuous vent valves of affected component/system. Personnel at the scene will dog WT doors and secure all bulkhead penetrations in affected compartment.

If applicable, secure battery charge; secure diesel engine; shut outboard and inboard engine snorkel exhaust valves.

(2) If a serious state of flooding exists under initial conditions like those underlying 3a, except that initial speed is ≅ 4 knots, recovery action will depend on capability of propulsion system to accelerate.

(a) If propulsion/electrical system status includes: steam in engine room; main engines warmed up, in operation or on jacking gear; at least one SSTG in normal operation; at least one SSMG in normal operation; action will be the same as in the basic sequence of 3a, except OOD will order "ahead full" and "answer bells on main engines" if latter is not already being done, for example, EPM in operation; EOOW/EPOOW will shift propulsion to main engines and

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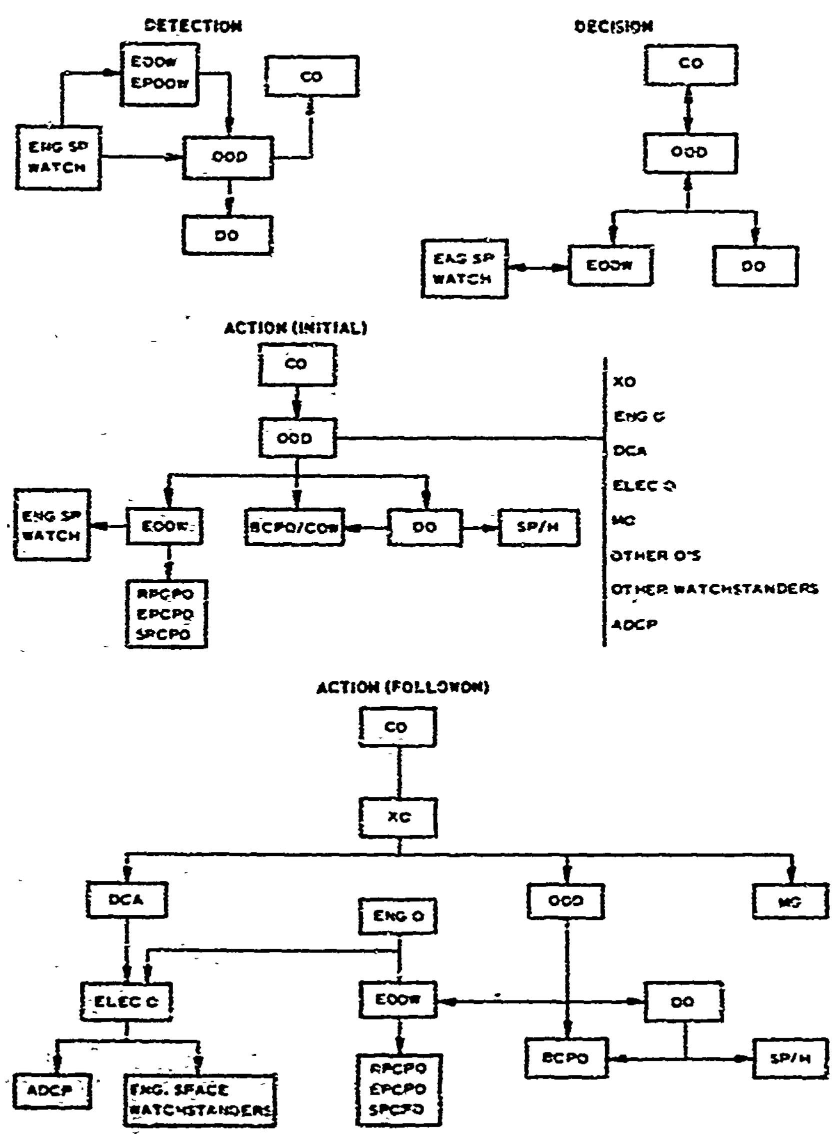
answer ordered bell as soon as possible; and local personnel will respond to EOOW/EPOOW orders, secure EPM, take main engine off jacking gear, and engage clutch.

(b) If propulsion/electrical system is lined up for reactor creep, the following conditions prevail - propulsion on EPM, reactor critical, one or two SSMG's running, main steam stops shut, main engine on jacking gear, no vacuum on condensers, MSW secured or one pump on SLOW and MSW cross-connect open, and SSTG's on jacking gear. Immediate recovery action under the above circumstances would be limited to emergency blow of the MBT's and isolation of the flooding.

4. INFORMATION FLOW DIAGRAM



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5. FOLLOWON ACTION/FEEDBACK

a. Results - Indication of Results of Initial Action

(1) CO/OOD/DO makes observations of ship's response, including the ship's angle, depth change rate, depth, speed, air-bank pressure, and roll and turbulence.

(2) Watchstanders/Local Personnel report the specific location of flooding, equipment affected or about to be affected by flooding, ability to isolate flooding, flooding rate, amount of water taken aboard, and equipment secured while combatting flooding.

(3) EOOW/EPOOW digest confirms watchstanders' report, status of propulsion and electrical systems and estimated remaining operating time, and status of hydraulic, air-conditioning, air-regeneration systems, and engine rpm.

b. Determine Supplemental Actions Required

(1) OOD/DO

(a) Adjusts plane angles.

(b) If emergency blow has not been previously ordered and ship is responding unsatisfactorily, orders emergency blow.

(c) Orders compartment bilges pumped if consistent with tactical situation; compensates for flooding by pumping from variable ballast tanks.

(d) If emergency blow has been ordered and ship is endangered by excessive roll and turbulence, reduce blow rate.

(2) Local Personnel

(a) Continue component/system isolation.

(b) Commence emergency repair within their capabilities.

(3) EOOW/EPOOW

(a) Ensure bells are answered as directed, within capability of propulsion plant.

(b) Continue lineup of power plant for most reliable operation consistent with flooding conditions.

(c) Restore to operation all systems previously secured that did not cause flooding and which are essential to recovery or personnel well-being.

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(d) Prepare lineup for compartment dewatering.

c. Indication of Followon Results

(1) Watchstanders/Local Personnel

(a) Off-watch personnel arrive at stations in accordance with General Emergency and Damage Control Bill.

(b) Information of 5a(2) is updated.

(c) Electrical Officer relieves EOOW at scene.

(2) Engineering Officer/EOOW

(a) Engineering Offic r arrives at station and assumes supervisory responsibility.

(b) EOOW resumes watchstanding functions.

(c) Information of 5a(3) is updated.

(3) Ship Status

(a) Followon conditions of basic recovery procedure are decreasing depth (stable rate), maintainable up angle $\leqq$ 30 deg, ahead speed $\cong$ 5 knots, depth approaching 150 ft, reserve-air-bank pressure, flooding confined to affected compartment, flooding rate reduced, and excessive roll and turbulence may be experienced as a result of emergency blow.

(b) Followon conditions of alternate recovery procedures are the same as 5c(3)(a) except MBT not blown and ahead speed $\cong$ 0 and up angle not closely controllable.

d. Determine Action Required to Complete Recovery - Identify desired (safe) operating envelope and identify action required using information of 5c.

e. Complete Casualty Recovery

(1) Representative action for completion of basic recovery procedure.

(a) Secure MBT blow.

(b) If ascent continues at approximately same rate and angle remains controllable, decrease up angle to level off ship at desired depth.

(c) If depth can be maintained with slight down angle, adjust speed to between 5 and 10 knots and cycle vents (forward-aft).

(d) May pressurize flooded compartment when ship is on or near surface.

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(2) Representative action for completion of alternate recovery procedure is same as 5e(1).

(3) Representative action for completion of alternate recovery procedure.

(a) Start up powerplant in accordance with emergency procedures.

(b) Regulate MBT blow and pump variable tanks to maintain a safe attitude and a depth consistent with the tactical situation.

(c) When speed of 5 to 10 knots is attained, perform actions of 5e(1).

G - FLOODING: REACTOR COMPARTMENT OR AMR NO. 1

1. RECOGNITION

a. Initial Conditions - The submarine is assumed to be operating at deep depth. Speed is 8 to 15 knots. Buoyancy is slightly positive. Basic variables relevant to detection of a casualty consist of ordered attitude and trim. Other important variables include (1) reactor plant is on the line and (2) rig status, that is, piping lineup of ASW system and reactor emergency cooling system in AMR No. 1.

b. Detection

(1) Detection of Impending Casualties

(a) Watchstanders or local personnel[a] note leakage in AMR No. 1 or the watch detects water in the reactor compartment during periodic inspections.

(b) If excess water in the bilges is not detected by watchstanders, control may note a change in trim.

(2) Detection of Flooding in the Reactor Compartment - Flooding may occur only via the demineralizer overboard discharge, a 2-in. line, so that direct flooding is highly improbable unless a bulkhead of an adjacent compartment is flooded. The other mode of flooding would be through the drain system into bilges. First indication would probably be the sounding of the bilge level alarm system. It is difficult to see all the space during the normal routine inspection, although a remote-controlled mirror is of aid.

[a] AMR No. 1 watch, standby reactor operator/auxiliary electrician aft machinery watch supervisor, engine room supervisor, EOOW.

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(3) Detection of Flooding in the AMR No. 1

(a) Hull penetrations that may serve as sources of flooding include the following:

Reactor emergency cooling heat exchanger

SW discharge and suction, 5 in.

Capsule access trunk chain, 1 in.

AMR ASW overboard discharge and suction, 3 in.

Depth control tank, flood and drain, 8 in.

Hydrogen overboard discharge, 1/2 in.

(b) Flooding by failure of internal piping may occur in AMR No. 1 in either the refrigeration or electronic cooling system of the ASW system.

(c) First indication of flooding in AMR No. 1 would be sight and sound sensations by watchstanders and/or local personnel.

2. DECISION MAKING

a. OOD/CO

(1) Ship Characteristics - Note speed, depth, attitude, trim/buoyancy, and reported nature and location of flooding.

(2) Crew Characteristics - Assess crew capability, state of training, physiological/psychological condition, and reaction time.

(3) System Status - Assess status of essential ship systems, for example, propulsion, hydraulic system, MBT flow system, variable ballast system, air-bank pressure/capacity, and communications.

(4) Possible degradation of essential systems due to flooding

(a) AMR No. 1 - Flooding may short out motors and other electrical components of the electronic cooling systems and external hydraulic system, elecronic cooling system may have to be secured as part of flooding isolation, and 400-cps MG sets may be shorted out with resultant loss of power to ship control indicators.

(b) Reactor Compartment - One major problem would be chloride stress corrosion; this may or may not affect the stainless steel piping in the reactor plant. Another problem would be contamination of the primary coolant system; this would degrade the system and require the plant to be shut down but would not have an immediate effect on recovery capability.

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(5) Special Consideration

(a) Access to the reactor compartment is delayed after shutdown, consistent with design limits.

(b) Temperature of the reactor plant will have to be reduced to minimize hazard of chloride stress corrosion.

(c) There is a very low probability that the steam generator will suffer thermal shock if the water gets very high.

(6) Recall special instructions, ship's standing orders and other constraints, for example, minimum depth, ice overhead, and surface ship activity.

(7) Recall available courses of action, for example, plane up to a shallower depth, engine full speed, engine moderate speed, blow MBT, and emergency blow MBT.

b. Local Personnel (Including Watchstanders)

(1) Determine what assistance is needed.

(2) Determine what immediate local action can be taken to stop the flooding, including isolation and emergency damage control; consideration will be given to such factors as accessibility to valves or remote controls and to the availability of suitable damage control materials.

(3) Make decisions relative to evacuation and isolation of the compartment.

c. Engineering Officer/EEOW

(1) Determine what powerplant and electrical system lineup will provide the most reliable operation.

(2) Determine whether or not the reactor must be shut down.

(3) Determine what systems in AMR No. 1 will have to be shut down as a result of ASW isolation and the effects on continued ship operation.

3. CORRECTIVE ACTION

a. Basic Sequence

(1) OOD/CO

(a) Pass the word to all hands

(b) Emergency blow MBT

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(c) Ship's speed of at least AHEAD 2/3.

(d) Attempt to maintain ship's angle of up 30 deg.

(e) Sound collision alarm

(f) Pump variable ballast tank

(2) Local Personnel

(a) Make initial report via 4 MC to control and maneuvering.

(b) Shut all ASW hull/backup valves and stop ASW pumps in the AMR No. 1 if flooded; dog WT doors and secure all bulkhead penetrations in affected compartment.

(3) EOOW

(a) Ensure that WT doors are closed and dogged, bulkhead flappers are shut, and recirculation blowers and precipitrons of AMR No. 1 and adjacent compartments are secured.

(b) If applicable, secure the battery charge, secure the diesel engine, and shut the outboard and inboard snorkel exhaust valves.

(c) Place the second MG and TG on the line.

(d) Change powerplant and electrical system lineups to ensure most reliable operation.

(e) Prepare to answer speed bells within powerplant limitations.

b. Representative Alternate Actions

(1) If the source of water influx can be isolated immediately, or if rate is low and if propulsion system, electrical and reactor control systems and ship control system are not affected, then the OOD may choose not to blow the MBT's and instead will plane up to a safer depth. Action will be taken as follows:

1. OOD

Passes word to all hands over 1 MC.

Orders speed AHEAD full.

Orders change to shallower depth consistent with tactical situation.

Diving officer maintains an up angle of up to 30 deg.

Sounds collision alarm.

2. EOOW/EPOOW

Prepares the power plant for maximum propulsion and electrical capability consistent with safety and reliability.

Passes the word via 2 MC to engineering compartment watchstanders.

Takes charge at the scene of casualty.

Ensures appropriate actions of 3a(3) above are taken; for example, closure of suction, discharge and continuous vent valves of affected component/system. Personnel at the scene will dog WT doors and secure all bulkhead penetrations in affected compartment.

If applicable, secure battery charge; secure diesel engine; shut outboard and inboard engine snorkel exhaust valves.

(2) If a serious state of flooding exists under initial conditions, like those underlying 3a, except that initial speed is ≦ 4 knots, recovery action will depend on capability of propulsion system to accelerate.

(a) If propulsion/electrical system status includes steam in engine room; main engines warmed up, in operation or on jacking gear; at least one SSTG in normal operation; at least one SSMG in normal operation, action will be the same as in the basic sequence of 3a, except OOD will order "ahead full" and "answer bells on main engines" if latter is not already being done, for example, EPM in operation; EOOW/EPOOW will shift propulsion to main engines and answer ordered bell as soon as possible; and local personnel will respond to EOOW/EPOOW orders, secure EPM, take main engine off jacking gear, and engage clutch.

(b) If propulsion/electrical system is lined up for reactor creep, the following conditions prevail - propulsion on EPM, reactor critical, one or two SSMG's running, main steam stops shut, main engine on jacking gear, no vacuum on condensers, MSW secured or one pump on slow and MSW cross-connect open, and SSTG's on jacking gear.

Immediate recovery action under the above circumstances would be limited to emergency blow of the MBT's and isolation of the flooding.

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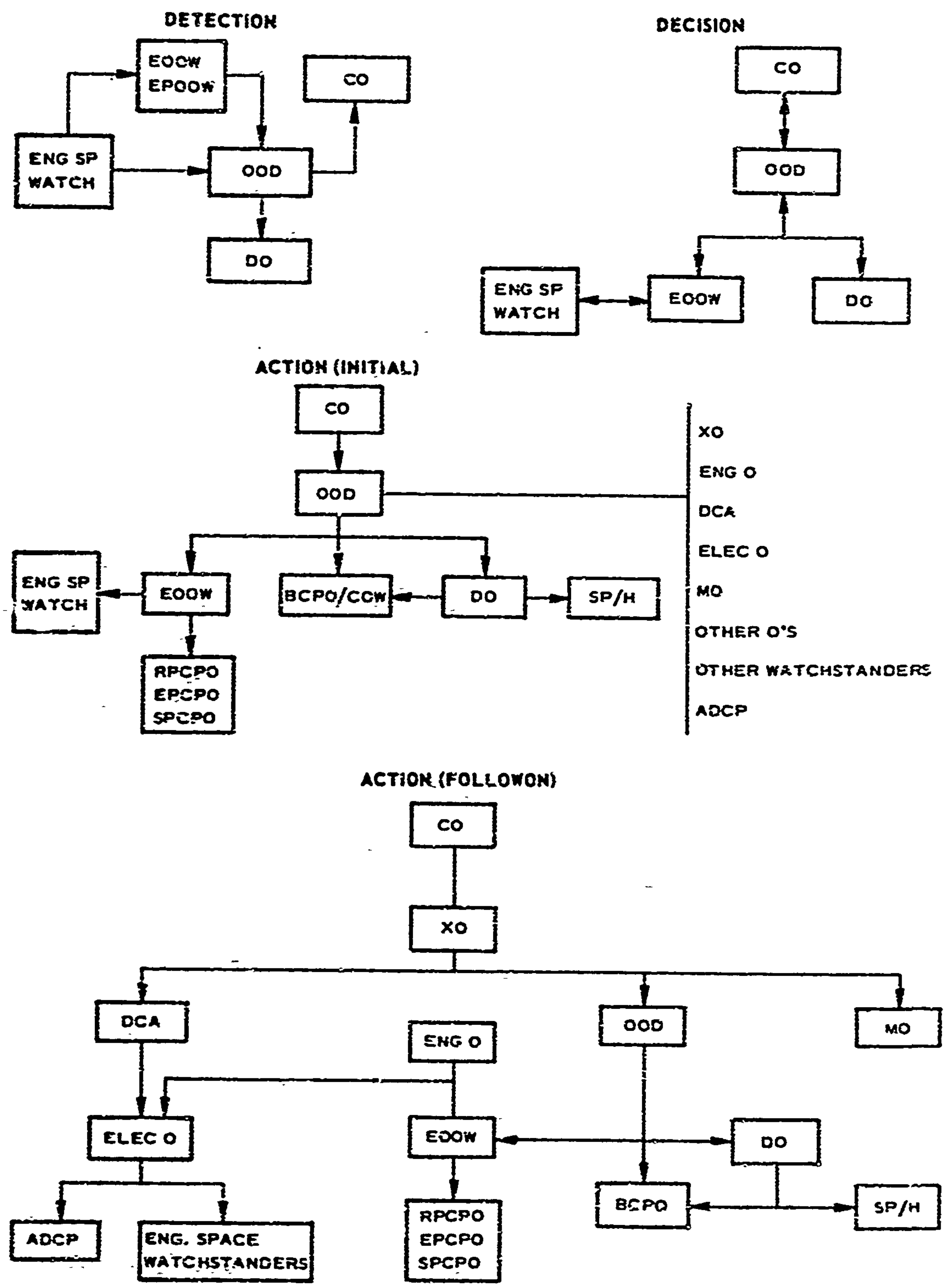
4. INFORMATION FLOW DIAGRAM



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5. FOLLOWON ACTION/FEEDBACK

a. Results - Indication of Results of Initial Action

(1) CO/OOD/DO makes observations of ship's response, including the ship's angle, depth change rate, depth, speed, air bank pressure, and roll and turbulence.

(2) Watchstanders/local personnel report the specific location of flooding, equipment affected or about to be affected by flooding, ability to isolate flooding, flooding rate, amount of water taken aboard, and equipment secured while combatting flooding.

(3) EOOW/EPOOW digest confirms watchstanders' report, status of propulsion and electrical systems and estimated remaining operating time, and status of hydraulic, air-conditioning, air-regeneration systems, and engine rpm.

b. Determine Supplemental Actions Required

(1) OOD/DO

(a) Adjusts plane angles.

(b) If emergency blow has not been previously ordered and ship is responding unsatisfactorily, orders emergency blow.

(c) Orders compartment bilges pumped if consistent with tactical situation; compensates for flooding by pumping from variable ballast tanks.

(d) If emergency blow has been ordered and ship is endangered by excessive roll and turbulence, reduce blow rate.

(2) Local Personnel

(a) Continue component/system isolation.

(b) Commence emergency repair within their capabilities.

(3) EOOW/EPOOW

(a) Ensure bells are answered as directed, within capability of propulsion plant.

(b) Continue lineup of powerplant for most-reliable operation consistent with flooding conditions.

(c) Restore to operation all systems previously secured that did not cause flooding and that are essential to recovery or personnel well-being.

(d) Prepare lineup for compartment dewatering.

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c. Indication of Followon Results

(1) Watchstanders/Local Personnel

(a) Off-watch personnel arrive at stations in accordance with General Emergency and Damage Control Bill.

(b) Information of 5a(2) is updated.

(c) Electrical Officer relieves EOOW at scene.

(2) Engineering Officer/EOOW

(a) Engineering Officer arrives at station and assumes supervisory responsibility.

(b) EOOW resumes watchstanding functions.

(c) Information of 5a(3) is updated.

(3) Ship Status

(a) Followon conditions of basic recovery procedure are decreasing depth (stable rate), maintainable up angle $\leqq$ 30 deg, ahead speed $\cong$ 5 knots, depth approaching 150 ft, reserve air bank pressure, flooding confined to affected compartment, flooding rate reduced and excessive roll and turbulence may be experienced as a result of emergency blow.

(b) Followon conditions of alternate recovery procedures are the same as 5c(3)(a) except MBT not blown and ahead speed $\cong$ 0 and up angle not closely controllable.

d. Determine Action Required to Complete Recovery - Identify desired (safe) operating envelope and identify action required using information of 5c.

e. Complete Casualty Recovery

(1) Representative action for completion of basic recovery procedure.

(a) Secure MBT blow.

(b) If ascent continues at approximately same rate and angle remains controllable, decrease up angle to level off ship at desired depth.

(c) If depth can be maintained with slight down angle, adjust speed to between 5 and 10 knots and cycle vents (forward and aft).

(d) May pressurize flooded compartment when ship is on or near surface.

(2) Representative action for completion of alternate recovery procedure same as 5e(1).

(3) Representative action for completion of alternate recovery procedure.

(a) Start up power plant in accordance with emergency procedures.

(b) Regulate MBT blow and pump variable tanks to maintain a safe attitude and a depth consistent with the tactical situation.

(c) When speed of 5 to 10 knots is attained, perform actions of 5e(1).

H - ATMOSPHERIC CONTAMINATION

1. RECOGNITION

a. Initial Conditions - The submarine is assumed to be operating at deep depth. Speed is 8 to 15 knots. Buoyancy is slightly positive.

b. Detection - The presence of toxic gases will be detected by local personnel directly in some cases by sensing odors, eye and throat irritations, headaches and nausea. In other cases abnormal concentrations will be detected by the Medical Department while performing periodic inspections using installed monitoring equipment and portable detection and analyzing equipment. Gases, inspected sources, method of detection and personnel involved are given in the attached table.

2. DECISION MAKING

The OOD and MO, upon receiving word that toxic gas is present, must first determine the type, amount (or lack), and location. This information may be included in the initial report by local personnel, or analysis may be required using installed and/or portable detection and analyzer equipment.

The seriousness of atmospheric contamination or oxygen lack must be assessed (see Table D-I). The capability for emergency air revitalization will be evaluated if applicable. Included in this consideration will be the possible use of the emergency oxygen supply or chlorate candles, use of CO_2 absorbent (LiOH), operation of the second CO-H_2 burner, and/or use of high-pressure air.

The need to decrease depth for purposes of emergency ventilation is determined.

TABLE D-I - ATMOSPHERIC CONTAMINATION RECOGNITION AND LOCAL ACTION

Gas	Source	Detection method	Personnel detecting	Local action
Low PO_2	Oxygen generator casualty	Period check of MK IV atmosphere analyzer or Beckman O_2 analyzer	Hospital corpsman/engineering lab tech	Use of O_2 bleed, chlorate candles, or high-pressure air banks
High CO_2	CO_2 scrubber casualty, fire extinguisher	Period check of MK IV atmosphere analyzer or Dwyer CO_2 indicator	Hospital corpsman/engineering lab tech	Use of LiOH, emergency ventilation
Acetylene	Storage tanks	Odor, engine room, and bow compartment	Watchstanders	Isolation and ventilation
Acrolein	Food frying, charcoal saturation	Odor, galley	Mess cooks	Isolation and ventilation
Amine	CO_2 scrubbers	Odor	AMR watch	Isolation and ventilation
Ammonia	CO_2 scrubbers	Odor	AMR watch	Isolation and ventilation
Carbon monoxide	Smoking, engine exhaust, cooking fire, $CO\text{-}H_2$ burner casualty	Period check of atmosphere analyzer and NBS CO detector	Hospital corpsman/engineering lab tech	Place second $CO\text{-}H_2$ burner on the line. Ventilation
Chlorine	SW in battery well	Atmosphere analyzer. Odor, burning of eyes, and throat.	Hospital corpsman/engineering lab tech or auxiliary elec. of watch, foward	Isolate and secure ventilation to battery compartment, then emergency ventilate
Formaldehyde	Combustion	Pungent odor	Watchstanders	Isolation and ventilation
Freon 12	Refrigerator and air-conditioning leaks	Atmosphere analyzer	Hospital corpsman/engineering lab tech	Isolation and ventilation
Hydrocarbons	Paints, cooking, and solvents	Atmosphere analyzer, pungent odor	Mess cooks, hospital corp/engineering lab tech, watchstanders	Isolation and ventilation
Hydrogen	Battery gassing, O_2 generator	Atmosphere analyzer	Hospital corpsman/engineering lab tech, AMR	Isolate compartment and then ventilate

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			watch, foward	
Formal-dehyde	Combustion	Pungent odor	Watchstanders	Isolation and ventilation
Freon 12	Refrigerator and air-conditioning leaks	Atmosphere analyzer	Hospital corps-man/engineering lab tech	Isolation and ventilation
Hydro-carbons	Paints, cooking, and solvents	Atmosphere analyzer, pungent odor	Mess cooks, hos-pital corp/engi-neering lab tech, watchstanders	Isolation and ventilation
Hydrogen	Battery gassing, O_2 generator	Atmosphere analyzer	Hospital corps-man/engineering lab tech, AMR watch, forward auxiliary elec.	Isolate compartment and then ventilate
Hydrogen chloride	Freon decompo-sition, $CO-H_2$ burners	Odor	AMR watch	Isolate compartment, shut down affected $CO-H_2$ burner and place 2nd burner on line. Ventilate compartment.
Hydrogen fluoride	Freon decompo-sition	Odor	Watchstanders	Isolation and ventilation
Methane	Sanitary tanks	Undetectable	. . .	. . .
Mono-ethano-lamine	CO_2 scrubbers	Odor	AMR watches	Isolate, take malfunction-ing equipment off line and ventilate
Ozone	Precipitators	Odor	Watchstanders	Isolate, deactivate mal-functioning equipment and ventilate
Phosgene (carbon chloride)	Freon decompo-sition	Odor (freshcut hay)	Watchstanders	Isolation and ventilation
Selenium	Electronic fire	Odor, purplish smoke	Watchstanders and control panel operators	Isolation, shut-down equipment source and ventilate
Smoke	Combustion	Odor and sight	Watchstanders and local per-sonnel	Isolation and emergency ventilation
Sulfur dioxide	Sanitary tanks	Odor	Watchstanders	Isolation and ventilation

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3. CORRECTIVE ACTION

a. OOD

(1) Pass the word to all hands via 1 MC.

(2) Sound the General Alarm.

(3) Place the General Emergency Bill into effect.

(4) Direct immediate action to locate and eliminate the source of toxic gas generation and/or isolate the affected compartment.

(5) If applicable, implement Emergency Air Revitalization portion of Air Revitalization Bill.

(6) If consistent with the tactical situation and the state of emergency, direct the ship's rise to snorkel depth or to the surface.

(7) Order emergency ventilation.

b. DO

(1) The diving officer will plane up to snorkel depth or surface as directed by the OOD.

(2) He will prepare to emergency ventilate and execute the order on command of the OOD.

c. Local Personnel - Upon discovery, local personnel will pass the word to control giving type of contamination or O_2 lack, amount, and compartment name. Carry out provisions of General Emergency Bill and Compartment Bills for toxic gas, including (1) shut and dog WT doors or as necessary to limit spread of toxic gas and (2) break out and be ready to don EBS masks.

d. MO - Determine type of toxic gas and concentration. Treat affected personnel. Advise the Commanding Officer of the physiological hazard in each case.

4. INFORMATION FLOW

Communication flow for this casualty is comparable to that for fire, with the exception that there is a definite communication link between the OOD/CO and the MO.

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5. FOLLOWON ACTION/FEEDBACK

a. Results - Indication of Results of Initial Action

(1) Local personnel observation of the status of contamination; success in identifying type and source, risk of toxic gas spreading, completeness of isolation and ventilation, and effects of contamination and isolation on other systems.

(2) Control room reports on local and affected compartment observations and ship status, for example, depth, speed, and attitude.

b. Determine Supplemental Actions Required

c. Indication of Followon Results

(1) Local personnel observation of the status of contamination: success in identifying type and source, risk of toxic gas spreading, completeness of isolation and ventilation, and effects of contamination and isolation on other systems.

(2) Control room reports on local and effected compartment observations and ship status, for example, depth, speed, and attitude.

d. Determine Action Required to Complete Recovery - Identify desired safe operating envelope and identify action required.

e. Complete Casualty Recovery

(1) Local personnel (includes COW, OOD, DO, and damage control party if required).

(a) Inspect locus of contamination

(b) Commence emergency ventilation, if required.

(c) Restore equipment to operation when safe to do so.

(d) Upon orders from control restore normal ventilation lineup.

(2) Control Room

(a) Order emergency ventilation of involved areas, if required.

(b) Order personnel protection (EBS/OBA) equipment secured.

(c) Order depth, speed, trim, etc., to operate ship within safe operating envelope consistent with tactical situation.

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I - COLLISION: SURFACED

1. RECOGNITION

a. <u>Initial Conditions</u> - Ship is at sea with normal steaming watch set. OOD and two lookouts are on the bridge. Upper and lower bridge access hatches are open. A speed of 10 to 15 knots is assumed.

b. <u>Detection</u> - Sharp roll and heavy vibration are felt. Sound of impact is heard.

c. <u>Verification</u> - Other ship and occurrence of casualty may be observed from the bridge if personnel are not lost or incapacitated.

2. DECISION MAKING

Implement the Collision Bill, the General Emergency Bill, and other applicable emergency bills such as fire and flooding.

3. CORRECTIVE ACTION

a. <u>OOD/CO/DO</u>

(1) Sound the Collision Alarm.

(2) Pass the word, "collision (location)" on 1 MC.

(3) Maneuver ship to maintain control and minimize flooding.

b. <u>COW/Auxiliaryman of the Watch</u>

(1) Shut induction and ventilation valves.

(2) Ensure that soundpowered phones are manned and that proper use is made of telephone circuits.

c. <u>EOOW</u>

(1) Secure the battery charge if in progress.

(2) Secure the diesel engine if running.

(3) Shut the outboard and inboard engine snorkel exhaust valves.

(4) Place a second MG and TG on the line and be ready to answer a bell on the main engines.

(5) Order ERUL watch to stand by the drain pump and to start the priming pump.

d. All Hands

(1) Shut the bulkhead flappers and deck hatches, including the lower bridge access hatch.

(2) Shut and dog all WT doors.

(3) Execute compartment collision bills.

(4) Be prepared to cope with flooding.

(5) Be prepared to fight fires.

(6) Be prepared to isolate electrically any compartment that suffers major flooding.

4. INFORMATION FLOW

Sound the collision alarm.

Pass the word to all hands over 1-MC.

5. FOLLOWON ACTION/FEEDBACK

a. Results - Indication of Results of Initial Action

(1) Location and nature of damage

(2) Status of essential ship systems; electrical, propulsion, hydraulics, control.

(3) Degree of isolation of collision effects such as fire and flooding.

b. Determine Supplemental Actions Required

(1) Complete actions of 3 above.

(2) Implement applicable emergency bills.

c. Indication of Followon Results

(1) Location and nature of damage.

(2) Status of essential ship systems; electrical, propulsion, hydraulics, control.

(3) Degree of isolation of collision effects, such as fire and flooding.

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d. Determine Action Required to Complete Recovery or Crew Survival Action

(1) The OOD/CO will assess the damage and status of essential ship systems. They will determine the location and direction of motion of the other ship. They will decide on emergency procedures to be effected and the safest ship operating envelope if the ship can be saved. If the ship cannot be saved the OOD/CO will execute the Abandon Ship Bill.

(2) The CO will make the decision to abandon ship "without delay" or with phased procedures.

(3) If personnel are left topside or lost overboard, Control will make the decision regarding rescue. Status of the ship will be evaluated in making this determination.

e. Complete Casualty Recovery/or Crew Survival Action

(1) Maneuver the ship as feasible to minimize flooding and maintain the ship on the surface.

(2) Pressurize the flooded compartment.

(3) Complete action to isolate and control fire and/or flooding.

(4) If ship cannot be saved, implement the abandon ship bill.

(5) If personnel are left topside or washed overboard and ship control is maintained, implement the Man Overboard Bill as applicable consistent with ship recovery and casualty control.

J - COLLISION: SUBMERGED

1. RECOGNITION

a. Initial Conditions - The assumption is made that the ship must ascend from deep submergence. Speed will be 8 to 15 knots. Rise angle will be 30 deg. Ship has positive buoyancy. (Sea state may vary from 1 to 6. Surface visibility is assumed to be that of night-time without moon.)

b. Detection

(1) Detection of Impending Casualty

(a) Sonar contacts may or may not be received below periscope depth.

(b) Collision may be perceived as imminent (visual) at periscope depth (contact close aboard, bearing rate - 0 deg.)

(2) Detection of Existing Casualty

Sharp roll, heavy vibration, and sound of impact.

2. DECISION MAKING (OOD)

If sonar contacts are received below periscope depth, OOD will weigh the tactical situation, urgency of surfacing, estimated range of nearest contact, evasive capability of own ship. Courses of action considered will include leveling off at safe depth to conduct sonar search or if urgency dictates, raising periscope and proceeding to surface. In the latter case steps will be taken to minimize damage.

If collision appears imminent at periscope depth, OOD will consider emergency actions to avoid collision and minimize damage. Actions considered will include flood tanks, rudder hardover, dive, speed change - ahead full or emergency back as appropriate to avoid collision orminimize damage.

If collision occurs without forewarning, the OOD control will follow the General Emergency Procedures.

3. CORRECTIVE ACTION

a. Sonar Contacts - If sonar contacts are received below periscope depth, action will be taken as follows:

1. Level off at safe listening depth.
2. Slow by all stop or backing.
3. Conduct SONAR search.
4. Change course (fish tail) to ensure complete sonar search.
5. If time permits, track contacts to determine direction of motion, estimated range, and bearing rate.
6. Maneuver ship to avoid zero bearing rate contacts.
7. Set Condition Baker, that is, shut and dog WT doors, shut bulkhead flappers, shut all main vents.
8. Raise the highest periscope.
9. Proceed smartly to periscope depth; perform visual periscope checks.
10. As soon as periscope breaks water, conduct

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a surface search on low power. If contacts appear at safe range, shift to high power and conduct second search.

b. Collision - If collision appears imminent at periscope depth, action will be taken as follows:

1. Sound collision alarm.
2. Order emergency deep or emergency back as appropriate to avoid collision.
3. Maneuver ship to minimize damage and/or flooding.
4. Lower all masts and periscope if undamaged.
5. Pass the word.

If the collision occurs, action will be taken as follows:

1. Control room
   a. Sound collision alarm.
   b. Pass the word.
   c. Maneuver the ship to minimize damage and/or flooding.
   d. Lower masts and periscopes if it can be determined they are undamaged.
   e. Shut all main vents.
   f. Shut outboard and inboard inductions and ventilation exhaust valaves.
   g. If snorkeling, secure snorkeling.
   h. Secure air revitalization procedures if in progress.
2. EOOW
   a. Secure battery charge if in progress.
   b. Secure diesel engine if running.
   c. Shut the outboard and inboard engine exhaust valves.
   d. Order ERUL watch to stand by the drain pump and to start the priming pump.
   e. Place a second MG and TG on the line and be ready to answer any bells on the main turbines.
3. All hands
   a. Shut bulkhead flapper and deck hatches,

including the lower bridge access hatch.

b. Shut and dog all WT doors.

c. Execute compartment collision bills.

d. Be prepared to cope with flooding, using available materials.

e. Be prepared to fight fires; isolate steam, water, chlorine, and oil leaks.

f. Be prepared to isolate electrically any compartment that suffers major flooding.

g. Report nature and location of damage.

4. INFORMATION FLOW

Sound the collision alarm.

Pass the word to all hands over IMC.

5. FOLLOWON ACTION/FEEDBACK

a. Results - Indication of Results of Initial Action

(1) Results of action to avoid imminent collision is the same as 3a and 3b.

(a) Avoidance or nonavoidance of collision.

(b) Location and motion of other ship.

(c) Ship status: direction, depth, depth rate, speed, etc.

(2) Results of action to combat collision effects.

(a) Reported location and nature of damage.

(b) Status of essential ship systems: electrical, propulsion, hydraulics, control.

(c) Degree of isolation of collision effects, such as fire and flooding.

(d) Ship control status and rates: speed, depth, attitude.

b. Determine supplemental actions required - Complete actions of 3.

c. Indication of Followon Results - Same as 5a.

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d. Determine Action Required to Complete Recovery

(1) If imminent collision is detected and successfully avoided by going deep, etc. the OOD determines the location and direction of the other ship and of other contacts. Then he will determine maneuvers required to remain clear and to return to a safe operating envelope.

(2) If collision is sustained, the OOD or DO assesses the damage and the status of essential ship systems. He determines the location and direction of motion of the other ship. He decides on emergency procedures to be effected and the safest ship operating envelope.

e. Complete Casualty Recovery

(1) Representative action, if imminent collision was averted

(a) Level off at safe listening depth.

(b) Adjust speed.

(c) Regain trim desired for depth and sea state.

(d) Maneuver to remain clear.

(e) Secure from collision quarters when ship is no longer in danger, that is, secure from Condition Baker and restore normal watch routine.

(2) Representative Action if Collision was Sustained

(a) Ship control - Level off at safe listening depth; adjust speed to maintain depth consistent with damage.

(b) Damage control - Carry out provisions of other emergency bills as required (fire, flooding, etc.).

APPENDIX E

TRAINING REQUIREMENTS ANALYSIS AND CREW POSITION RESPONSIBILITIES

I - CASUALTY(IES): PLANE AND RUDDER FAILURES

A - PERSONNEL: HELMSMAN, STERN PLANESMAN, DO, OOD, COW, OFF-LOOKOUT (OR LEE HELMSMAN)

B - PART TASK GROUPING

1. HELMSMAN RESPONSIBILITIES

The helmsman responsibilities are:

1. Select control mode.
2. Select course and depth on AMC control panel.
3. Ring up ordered engine bells and acknowledge orders.
4. Control (normal) rudder to gain and maintain ordered course.
5. Control (normal) fairwater planes at moderate to shallow depth to reach and maintain ordered depth.
6. Monitor indicators to ensure correct operation of indicators, fairwater planes, and rudder and to ensure correct operation of the ship:

   Combined instrument unit indicators are gyro course, rudder angle, depth, trim angle, depth error, depth rate, and course error.

   Other indications are deep depth gage, shallow depth gage, digital depth indicator, speed indicator, engine order indicator, gyro course indicator, fairwater planes angle (normal and emergency), rudder angle (normal and emergency), and Magnesyn Indicator.
7. Notify DOOW of improper indications or failure.
8. Test periodically plane and rudder control (both normal and emergency modes).
9. Switch plane and rudder control to emergency power, activating power transfer pilot valves

(or 700 psi air in case of 594 class ships) if required.

10. Test and operate planes in rate control (emergency power).
11. Request the lee helmsman to man emergency steering station.
12. Request lineup of hydraulic system for emergency positioning pump operation: (a) fairwater planes - lee helmsman, (b) stern planes and rudder - aft auxiliary electrician on phones; engine room upper level watch or machinery watch supervision on controls.
13. Exercise combined control of steering and planes using single stick (optional task).
14. Open or close valve, as appropriate, to operate or isolate shallow depth gage. Depth limit for safe gage operation is about 200 ft.
15. Acknowledge and report fulfillment of orders by OOD and DO.
16. Operate fairwater planes to compensate for stern plane failure or as directed by the DO.

2. STERN PLANESMAN RESPONSIBILITIES

The stern planesman responsibilities are:

1. Select control mode.
2. Select depth control mode.
3. Select course and depth control on AMC control panel.
4. Control stern planes (at moderate-to-shallow depth) and/or slow speed to maintain desired ship angle.
5. Control stern planes at deep depth to maintain depth and angle.
6. Monitor indicators to ensure correct operation of indicators and stern planes and to ensure correct operation of ship.

   Combined instrument unit indicators are gyro, rudder angle, depth, trim angle, depth error, depth rate, and course error.

   Other indications are deep depth gage, shallow depth gage, digital depth indicator, speed indicator, stern planes angle indicator (normal

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and emergency), trim angle bubble indicator, and hydraulic and electrical system alarms.

7. Notify DO of improper operation or failure.
8. Test plane control periodically in both normal and emergency modes.
9. Switch stern plane control to emergency power, activating power transfer pilot valves (or 700 psi air in case of 594 class ships).
10. Test and operate planes in rate control (emergency power).
11. (Optional task) Exercise combined control of steering and planes using single stick.
12. Acknowledge and report fulfillment of orders by DO.

3. DO RESPONSIBILITIES

The prerequisites for detection and prevention of impending casualties are:

1. Perform trim analysis and control.
2. Monitor plane angles used by helmsman and planesman to ensure planes are operated judiciously consistent with speed and depth.
3. Order ship angle or depth rate during depth change for safe operation consistent with speed and depth.
4. Order steering and diving control mode.
5. Coordinate activities of planesmen to ensure minimum operation of control surfaces.
6. Supervise diving and surfacing evolutions.
7. Monitor BCP and diving stand indications to ensure status of equipment is safe for submerged operation.
8. Keep informed of the navigational factor involving safe submerged control of ship.
9. Keep informed of power plant status.
10. Monitor and compensate for sound velocity conditions (layers).
11. Acknowledge and carry out orders received from OOD.
12. Order plane and rudder control.
13. Order shift of steering and diving control mode.

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14. Request speed change if not ordered by OOD.
15. Detect improper indication or operation of control surfaces.
16. Order blowing of MBT's (normal or emergency).
17. Order sound powered phone communication established with engine room.

4. OOD RESPONSIBILITIES

The OOD responsibilities are:

1. Supervise the overall operation of ship control party.
2. Monitor and supervise control of depth, course, and speed.
3. Evaluate tactical and navigational factors involving safe control of ship.
4. Use periscope, sonar, and UQC to ensure that tactical situation will permit safe performance of planned depth change or maneuver.
5. Keep informed of power plant capabilities.
6. Keep informed of blow system status including air bank pressures and vent positions.
7. Control rig status.
8. Select angle for depth change and set plane angle limits.
9. Order mode of control for control surfaces.
10. Order emergency recovery actions consistent with casualty, including engine orders, MBT blow and venting, depth changes, and rudder movements.
11. Ensure that nature of emergency is passed on 1 MC.
12. Notify ships in vicinity as appropriate; order firing of emergency recognition signal.

5. LEE HELMSMAN RESPONSIBILITIES

The lee helmsman responsibilities are:

1. Perform emergency control of rudder (operates emergency positioning control of the fairwater planes).

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2. Man control room phones as directed.

6. COOW RESPONSIBILITIES

The COOW responsibilities are:

1. Emergency blow MBT's in event of stern planes fail on dive.
2. Secure blow, and vent the tanks as ordered by DO.
3. Monitor and operate hydraulic plants as required. This includes selecting pump operation, monitoring accumulator levels, monitoring overtemperature and low air pressure alarms and operating control power transfer switch.
4. Operate trim system as ordered by DO.
5. Monitor air bank pressures and blow system lineup.
6. Acknowledge and report fulfillment of orders to OOD and DOOW.

II - CASUALTY(IES): FIRE

A - PERSONNEL: LOCAL WATCHSTANDERS, ALL HANDS, OOD, DO, EOOW, COW, HELMSMAN/PLANESMAN

B - PART TASK GROUPING

1. LOCAL PERSONNEL RESPONSIBILITIES

The local personnel responsibilities are:

1. Exercise precautions to minimize possibility and seriousness of fire by observing of ship's regulations and standard safety precautions.
2. Detect presence of fire or overtemperature condition.
3. Identify type of fire, its location, and equipment involved.
4. Pass word to control or maneuvering as appropriate.
5. Combat fire with means available appropriate to type of fire.
6. Call for assistance in rigging compartment in accordance with compartment bill.

7. De-energize affected electrical equipment.
8. Remove all explosive and combustible material.
9. Provide amplifying reports as soon as practicable.

2. ALL HANDS RESPONSIBILITIES

The all hands responsibilities are:

1. Designated persons proceed to scene of emergency in accordance with ship's general emergency bill.
2. Shut bulkhead flappers.
3. Secure compartment recirculation blowers and precipitrons.
4. Secure bleeding oxygen in ship.
5. Shut all deck hatches.
6. Set watertight doors of nonaffected compartments in accordance with general emergency and fire bills.
7. Break out and stand ready to don EBS masks.
8. Pass fire extinguishers one compartment toward scene of fire maintaining at least two extinguishers at each bulkhead adjacent to fire.

3. OOD RESPONSIBILITIES

The OOD responsibilities are:

1. Sound general alarm and pass word as to nature and location of emergency.
2. Evaluate tactical and navigational situation.
3. Evaluate possible ship control action, taking into account seriousness of fire and readiness to meet subsequent casualty that may result from fire.
4. Order ship control actions as appropriate to prepare ship for emergency ventilation.
5. Order lineup for emergency ventilation, if required.
6. Ensure all hands action is completed in accordance with general emergency and casualty bill.

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4. DOOW RESPONSIBILITIES

The DOOW responsibilities are:

1. Implement changes in depth as ordered by OOD.
2. Shut outboard and inboard inductions and ventilation exhaust valves.
3. Stand prepared to surface, if ordered.

5. EOOW RESPONSIBILITIES

The EOOW responsibilities are:

1. Pass word to control and sound general alarm.
2. Take charge at scene and supervise control until relieved.
3. Estimate effects of fire and local corrective action on propulsion, electrical, and hydraulic systems and report to control.
4. Estimate effect of fire and corrective action on ship's atmosphere and report to control.
5. Ensure that affected compartment is isolated.
6. Evacuate all nonwatchstanding personnel unless required at the scene.
7. Order EBS/OBA used as required.
8. Secure battery charge if in progress.
9. Secure diesel engine if running.
10. Shut outboard and inboard engine snorkel exhaust valves.
11. Place second MG and TG on line.
12. Keep OOD informed of any significant changes or plant limitations.

6. COOW RESPONSIBILITIES

The COOW responsibilities are:

1. Monitor communications and act as communicator for OOD.
2. Estimate effect of fire and local corrective action on electrical, control, navigation, radar/sonar, and weapon systems.

3. Estimate effort of fire and corrective action on ship's atmosphere.
4. Supervise handling of emergency from control until relieved by officer.
5. Ensure that affected compartment is isolated.
6. Call for emergency assistance, as required.
7. Evacuate all nonwatchstanding personnel unless required at scene.
8. Order EBS/OBA used as required.
9. Keep maneuvering and control informed of status.

III - CASUALTY(IES): FLOODING

A - PERSONNEL: LOCAL WATCHSTANDER, OOD, DO, EOOW, COW, HELMSMAN/PLANESMAN

B - PART TASK GROUPING

1. LOCAL WATCHSTANDER RESPONSIBILITIES

The local watchstander responsibilities are:

1. Monitor/check potential sources of flooding.
2. Recognize degree of water influx; differentiate water spray from other high pressure sprays.
3. Determine location and source of flooding or leakage if feasible.
4. Determine equipment that may be immediately affected by the water.
5. Report leakage or flooding to control or maneuvering as appropriate.
6. Sound collision alarm, if locally available.
7. Isolate affected system by closing valves upstream and downstream of unit, manually closing backup valves and hull valves for which controls are available.
8. If unable to close valves locally, request assistance (all sea water piping 4 in. or larger will be isolatable from maneuvering in engine and AMS/AMR No. 2 compartments).
9. Take emergency damage control action as feasible.

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10. Call for assistance in manning phones and carrying out compartment isolation procedure; e.g., shut bulkhead flappers and deck hatches, dog watertight doors, and carry out provisions of compartment collision bills.
11. Electrically isolate affected area.
12. Make followup amplifying report of casualty status and success in isolating casualty.

2. OOD RESPONSIBILITIES

The OOD responsibilities are:

1. Pass word over 1 MC, denoting nature and location and sound the collision alarm.
2. Supervise overall operation of ship control party.
3. Monitor and supervise control of ship's angle, depth and depth change rate, and speed.
4. Keep informed of status of essential systems for recovery by observation and phone communication: propulsion, hydraulics, MBT blow system, and communications.
5. Evaluate tactical situation and take into account special instructions from CO.
6. Inform CO/XO of casualty situation.
7. Control rig status.
8. Order emergency recovery actions consistent with casualty including engine orders, MBT blow and venting, depth changes, and rudder movements.
9. Notify ships in the vicinity as appropriate; order firing of emergency recognition signal.

3. DO RESPONSIBILITIES

The DO responsibilities are:

1. Maintain trim control so as to facilitate control and recovery in case of flooding.
2. Monitor ship control indications to detect abnormal response due to undetected flooding or leakage.
3. Monitor BCP and diving stand indicators

to ensure status of equipment is safe for submerged operation.

4. Keep informed of tactical navigational factors involving safe submerged control of ship.
5. Acknowledge and carry out orders of OOD.
6. Order emergency ship control recovery actions in consonance with orders from OOD, including plane and rudder angles, ship angle, MBT blowing/venting, and speed changes.
7. Order shift of steering and diving control mode if required.

4. EOOW RESPONSIBILITIES

The EOOW responsibilities are:

1. Verify location and rate of flooding.
2. Review status of essential equipment.
3. Know rig status of sea water systems.
4. Take charge at scene and supervise control of damage until relieved.
5. Remotely activate closure of ASW hull stop valves.
6. Isolate affected side of MSW system
   a. Secure hull, backup and cross-connect valves.
   b. Secure MSW pump.
   c. Secure main engine steam flow.
   d. Shift SSTG loads to unaffected side and secure steam to affected SSTG.
7. Check and/or switch main coolant system to SLOW. Answer speed bells within power plant limitation.
8. Secure battery charge, diesel generator, and outboard and inboard engine snorkel exhaust valves.
9. Pass word to control and sound the collision alarm. Also pass word to engineering watches.
10. Make followup amplifying report of casualty status.
11. Secure diesel engine if running.

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12. Shut outboard and inboard engine snorkel exhaust valves.
13. Place second MG and TG on line.
14. Keep the OOD informed of any significant changes, or plant limitations.

5. COW RESPONSIBILITIES

The COW responsibilities are:

1. Monitor communications and act as communicator for OOD.
2. Monitor air bank pressure and report status to OOD and DO.
3. Check status of masts and other hull openings.
4. If snorkeling, secure engine and shut outboard induction and exhaust valves.
5. Perform emergency operations in response to orders from DO and OOD: e.g., operate trim pump, operate drain pump (SSBN only), request engine room operate drain pump (SSN), actuate MBT blow (emergency or normal), operate vents, and start second lead pump.
6. Monitor hydraulic system operation and take action as required to maintain plane and rudder control power.

IV - CASUALTY(IES): ATMOSPHERIC CONTAMINATION

A - PERSONNE' 'OCAL PERSONNEL, MO, OOD

B - PART TASK GROUPING

1. LOCAL PERSONNEL RESPONSIBILITIES

The local personnel responsibilities are:

1. Pass word to control of maneuvering.
2. Carry out provisions of general emergency bill and compartment bills for toxic gas.
3. Shut and dog WT doors of affected compartment.
4. Break out and stand ready to don EBS masks.

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2. MO RESPONSIBILITIES

The MO responsibilities are:

1. Determine type of toxic gas and concentration, if possible.
2. Advise CO of hazard involved.

3. OOD RESPONSIBILITIES

The OOD responsibilities are:

1. Pass word and sound the general alarm.
2. Direct action to locate and eliminate source of toxic gas generation.
3. Emergency ventilate using low pressure blower on orders of CO.

4. DO RESPONSIBILITIES

The DO responsibilities are:

1. Prepare for emergency ventilation and emergency ventilates on orders from OOD.
2. Change depth as ordered by OOD.

V - CASUALTY(IES): COLLISION

A - PERSONNEL: OOD/CO, ALL HANDS

B - PART TASK GROUPING

1. OOD/CO RESPONSIBILITIES

The OOD/CO responsibilities are:

1. Collision prevention: (a) level off at safe listening depth, (b) slow down, (c) conduct SONAR search, (d) maneuver ship to avoid zero bearing contacts, (e) set condition BAKER, (f) raise highest periscope, and (g) proceed smartly to periscope depth; perform visual periscope checks.
2. Reaction to imminent collision: (a) sound collision alarm and pass word, (b) order emergency deep or emergency back as appropriate to avoid collision, (c) maneuver

ship to minimize damage and/or flooding, and (d) lower all masts and periscope if undamaged.

3. Recovery from collision: (a) sound collision alarm, (b) pass word to all hands over 1 MC, (c) maneuver ship to maintain control and minimize flooding, (d) order masts and periscopes lowered if it can be determined they are undamaged, (3) order all main vents shut, (f) order outboard and inboard inductions and ventilation exhaust valves shut, and (g) order snorkeling secured, if necessary.

2. ALL HANDS RESPONSIBILITIES

All hands responsibilities are to perform general emergency and compartment collision bills and to report nature and location of damage.

APPENDIX F

RECOMMENDED CHARACTERISTICS FOR NEW DYNAMIC SUBMARINE CASUALTY CONTROL TRAINER FACILITY

1. GENERAL TRAINING FACILITY REQUIREMENTS AND ASSUMPTIONS

a. General

The dynamic submarine casualty ship control trainer should be adaptable to simulate all types and classes of submarines in existence or in the construction process. The trainer will include the capability for teaching both normal and emergency procedures, since effective normal performance is inextricably interwoven with casualty prevention and effective casualty/emergency recovery action.

b. Submarines to be Simulated

The facility should be capable of being adapted to both types of nuclear submarines, SSN and SSBN. Also, the device as adapted to type should have the built-in flexibility sufficient to be programmed at the training centers so as to simulate faithfully ship performance and ship system characteristics of each class of ship within the type selected. Programming, equipment, software, and procedures should be such as to permit change of the trainer from class to class of ship to be simulated with a minimum of skill and knowledge and in a minimum of time.

c. Training

(1) General

The trainer will provide a means for training in the skills described as Items (2) through (5), below.

(2) Team Actions Involved in Diving, Surfacing, and Submerged Control of Today's High-Speed Deep-Diving Nuclear Submarines

The trainer should include the capability to demonstrate and provide practice for ship personnel progressively from simple to complex exercises involving (when the trainee is sufficiently proficient in normal evolutions and procedures) the following:

1. Combined heading and depth changes and trim condition effects

2. Full understanding of the safe operating envelope (depth, trim, angle, and speed) and

also sea state, general operating situation, and navigational factors (the latter two being verbally transmitted by the operator via the communications system)

3. Plane casualties and flooding emergencies, presented singly and in combination, which are likely to occur in each of the named evolutions

4. Effects on the ship's performance of No. 1, above, and their relationship to the ship operating envelope, such as depth band, trim, and ship angle and speed, and also to the general operating situation,[a] sea state, and navigational[a] factors.

5. Critical recovery factors and effects, for example, time required to stop flooding, planes and rudder action, speed, MBT blow and vent, special-tank (negative or hovering) blow and vent, low-pressure blow systems, compartment isolation,[a] etc.

(3) Normal, Emergency, and Manual Operation of Ship Control Systems Controllable by Ship Control Party

As described in Item (2), above, when trainees have gained sufficient proficiency in normal operation, the device should have the capability to demonstrate the effects of ship-control-system malfunctions on normal ship operation and personnel safety and on casualty/emergency recovery action.

Examples of ship systems[b] for which malfunctions will be simulated are hydraulics, propulsion (speed), electrical, MC communications, steam piping, auxiliary salt water (ASW), MBT blow and vent, and snorkel and mast systems.

(4) Procedures and Capabilities of Recovery from Flooding, Control Surface Jamming, Collision, and Other Casualty/Emergency Situations

As described above in Items (2) and (3), when trainees have reached

[a]Will require simulation solely by communications by the trainer operator rather than by use and any simulation logic or hardware, although it will be coordinated with simulated physical effects.

[b]Most system malfunction simulations will require the trainer operator to provide the simulated malfunction input to the trainee by communications representing initial and amplifying reports by local watchstanders.

or have the proper level of proficiency, the effects of errors (accumulated from years of submarine operation and casualty investigation) should be introduced. In particular, it should be possible to demonstrate sequential effects of errors that have followed a misunderstood announcement of a simple malfunction by a local watchstander, and that have resulted in ship sinkings and losses of men overboard. Communications should be particularly emphasized in this respect.

(5) Responsibilities of Personnel in Positions of OOD (Conning Officer), Diving Officer, BCP Operator, COW, Helmsman/Fairwater Planesman, Stern Planesman, and Lee Helmsman

All these personnel should be subjected to the training implied in Items (2), (3), and (4), above.

d. Inherent Capability

The trainer, being an advanced ship casualty control team trainer for ships' crews, inherently will have the capability for basic refresher and intermediate training in submarine control for individual and groups of individuals under both normal and abnormal conditions, even though the use of the advanced trainer to develop basic skills is not an economical or necessarily most effective approach.

e. Trainees

The trainees using this facility will be submarine officers and enlisted personnel possessing varied educational, professional, and submarine operational experience, from students in basic submarine school to submariners with many patrol missions. The training provided in any scheduled training session may be given to a group of individual trainees or a ship's team.

f. Instruction

A recommended training program and exercises should be furnished by the trainer contractor in a trainer operating manual as a basis for a standardized casualty control program. Specific training exercises will be coordinated between the using command and the training facility.

g. Instructors

The instructors will be facility personnel. They should be officers who are qualified in nuclear submarines. They will be assumed to possess a full understanding of the varied capability of the training device. The instructor's understanding of the device will be the joint responsibility of the facility personnel and the device contractor. This will include the capability to update instruction due to applicable state-of-the-art changes.

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h. Training Session Duration

It is assumed that the facility will be capable of being used 40 hr a week or more. The assumed length of a training problem is from 1 to 4 hr. A capability for use of the trainer on a double-shift basis is recommended to be compatible with training centers that have high trainer utilization requirements.

2. IMPLICATIONS OF DIFFERENCES IN CLASSES OF SHIPS

The characteristics recommended later in Items 3 and 4 of this appendix will apply to each class within the type of ship being simulated.

The trainer design should provide flexibility that will permit the trainer operators, without additional special skills, to readily change the computer complex and simulated ship-control station from class to class so as to represent faithfully the training party's ship.

The required capabilities for the trainer will include but not be limited to:

1. Spare wiring in cables between the BCP, diving station, and computer complex
2. Spare plugs in the simulated BCP and diving station
3. Flexible mountings for:
   a. BCP panels
   b. Diving-panels indications
   c. Planes/steering/AMC mode selector pedestal
   d. Emergency steering control
   e. Pilot transfer hydraulic control valves
4. Spare computer logic and input/output equipment
5. For conversion between SSN- and SSBN-types of submarines, a capability to convert or exchange BCP consoles because of major differences in pedestals and the inclusion of the missile compensation system for SSBN-type simulators; this is recommended for factory change or field retrofit.

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3. PHYSICAL REQUIREMENTS

The dynamic submarine ship-control trainer should include a ship-control platform, a computer complex, and an operator area. The ship-control platform should contain the steering and diving station, ballast control panel, adjacent emergency/manual controls, instructor's remote controls, miscellaneous system components, and personnel accommodations. It should have the following characteristics:

1. The cab configuration should be as similar as possible to that of the ship in regard to the workplace environments of the DO, BCPO, and planesmen. The OOD station should be duplicated only in terms of height and location

2. All normal and alternate controls and indications that are vital for ship control should be provided. Indications should be duplicated.

3. The platform should be free to move ± 45 deg in pitch and ± 30 deg in roll under control of the platform motion system.

4. The platform should have sufficient safety interlocks and controls to ensure personnel safety under any mode of operation of the platform motion system.

5. The instructor's remote controls should consist of a remote computer RESET-HOLD-OPERATE control and platform-motion safety leveling control.

6. The platform should be provided with safe riding accommodations for the following personnel:

   a. Two to three planesmen

   b. One to two ballast control panel operators

   c. One to two diving officers

   d. One to two officers of the deck/conning officers

   e. One instructor

   f. One to two observers (optional)

The computer complex should be adjacent to the area below the platform and should contain the computer, input/output equipment, maintenance workbench area, platform motion powerplant, and storage facilities. The arrangement of the complex and the area below the

platform should be combined to enhance the accessibility, sound isolation, safety, air conditioning for equipment and personnel, maintenance, storage, and record keeping.

The operator area should be adjacent to and at approximately the same height as that of the platform. It should contain the operator's console, scoring/monitoring equipment, and an observer/critique area. It also should provide for safe entrance and exit to and from the platform. The operator's console should be arranged and situated to provide the operator with the necessary controls, communications, monitors, (simulated MC and sound powered phone systems) and observational advantage to operate the trainer adequately in cooperation with the instructor.

4. DYNAMIC SIMULATION REQUIREMENTS

a. General

The dynamic submarine ship-control trainer should faithfully simulate ship systems and hydrodynamics for the purpose of casualty control training as recommended in Items b through d, below.

b. Ship Systems Simulation

(1) General

The ship systems simulated should be those that are directly monitored and controlled, or indirectly monitored and controlled through communications by the ship control team. These systems include electrical and hydraulic control power, propulsion, MBT blow and vent, negative tank or hovering, trim and drain, planes and rudder, missile compensation, low-pressure blow, emergency propulsion, air regeneration, and air banks. The systems controlled should be simulated to the extent that all essential controls and indications at the control station are provided on the trainer on a one-to-one correspondence with the ships being simulated.

For the systems controlled, the logic should provide for erroneous operation by the trainee and operator control of the portion of the system to be simulated which is not automatic or trainee controllable. The indications should have time lags and dynamic responses that approach reasonably the time lags and dynamic responses of the comparable indications on the ship being simulated. The simulated outputs (including verbal status reporting) or systems that are controlled aboard ship via communications with local watchstanders, and the EOOW, should be controlled or provided by the operator using communications and on-off or variable controls as appropriate. The systems simulation also should provide for the insertion of malfunctions that will include indication failures, subsystem failures, and system failures.

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Individual system requirements that should be included are given in Items (2) through (6), below.

(2) Steering and Diving Systems (Including AMC)

The steering and diving systems will provide for the operation of all control surfaces in all modes of operation (including the AMC system) of the ship simulated. All control-surface position indications should reflect the rate appropriate for each mode of operation. The dynamic responses of the ship relative to mode selection and operation should be exhibited.

The simulated AMC system should be completely operable over the same range as that of the ship simulated. The trainer operator should be able to jam any combination of the control surfaces. Each control-surface jam should be either at the current position of the control surface or, at the option of the operator, in any position within the normal control-surface travel. The operator should be able to fail in each system, as applicable, control power for each mode, hydraulic power, normal plane position indication, emergency plane position indication, automatic emergency control-surface mode switching, electrical control power, and trim/drain control.

(3) Trim and Drain Systems

The trim and drain systems as controlled and monitored by the BCP should be operable. The pump rate will approximately correspond to motor speed control and depth. The sharing of pump flow and tank suction discharge lineup will be included.

The trainer operator will control the portion of the system not controlled from the BCP of the ship simulated. The initial neutral bouyancy and trim condition of the ship should be controllable by the operator. The operator should be able to fail the following: pump, prime pump, gallons pumped indications, tank capacity gages, valve control switches, and the electrical power supply to both tank cont l switches, indicator lights, and suction and discharge valves.

(4) MBT System

The individual and group operation of the vent and blow controls of all the tanks in the MBT system should be operable. Both high-pressure and low-pressure blow controls on the BCP of the simulated ship should be operable. During blowing, the pressure dynamics should be realistically indicated on BCP air gages.

Normal, emergency, and manual emergency means of blowing the MBT's should be operable. Simulation of interlock circuitry between individual or group tank controls should be considered. The

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capability to blow the MBT's with the vents open should be simulated. The blow and vent rates should include the effects of depth on the center of gravity and air pressure in individual MBT tanks. The amount of water in each tank should show expansion and contraction of air retained in the tanks as affected by depth and by the center of gravity of the tank. The simulation of list control should be considered.

The operator should be able to fail all or group MBT blow and vent. The modes of failure selectable by the operator should include switches, hydraulic power to vent valves, the electric power, and blow and vent valves in their position at the time of malfunction insertion.

(5) Other Systems

(a) Propulsion System

The simulation of propulsion-system effects should include the engine order transmitter and a normal delayed answer on the diving station. (A repeater might also be provided for the operator.) The speed should be generated for each "bell" corresponding to the speed-bell relationship used aboard the ship of the trainees. Simulated propeller reversal also should be provided. The operator (programmed or manual) should be able to fail either indicated engine-order response and to vary thrust (speed) from that ordered by the trainees.

(b) Snorkel System

BCP control and indications of the snorkel system should be simulated. The operator/trainer will provide simulated operation of related equipment, such as the diesel engine, as required. The proper pressure dynamic effects on gages during all operations and valve classing due to sea state and depth conditions will be provided. The operator should be able to fail the operation or indication of each status lamp provided on the BCP.

(c) Missile Compensation System

The missile compensation system should be simulated at the trainee's panel to the extent that it can be operated from the BCP. The operator/trainer will simulate missile firing and be capable of failing door controls and introducing low air and hydraulic power to the system.

(d) Hydraulic System

The hydraulic system should be operable from the BCP as it is on an actual BCP. Accumulator level, as affected by control-surface action, will be shown. The operator should control the simulated

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hydraulic system to provide for loss of hydraulic power in various systems, failure of trainee controls, and failure of trainee indications of pressures and/or levels.

(e) Electric Power

Both 60- and 400-cps electric power should be provided so that the effects of loss of either or both to the BCP or diving station will be contained in the simulation.

(f) Air System

The air system should be trainee operable and should show dynamic and static effects of pressure due to capacity and use for blowing. The initial conditions of pressure should be controllable by the operator.

(6) Miscellaneous Equipment Considerations

The bathythermograph shall be operable with water temperature at depth levels controllable by the operator.

All the instruments of the following types in the simulated control room should be driven by computer outputs: Shallow depth, deep depth, digital depth, depth error, ship speed, ship heading, course error, trim angle, roll angle, ordered depth transmitter, and ordered course transmitter. The on-off valves for depth gages will be provided.

The pitch and roll motion of the simulated ship will be provided to the ship-control platform. The pitch and roll will be mechanically limited to ± 45 and ± 30 deg, respectively, while the platform will display normal limiting action after reaching limits of ± 40 and ± 25 deg, respectively. Maximum safety to personnel, both on and around the platform,must be provided.

The AN/WIC, wound powered phone and alarm systems, should be provided. Those alarms that are part of the 1 MC will be provided.

c. Submarine Hydrodynamic Simulation

The submarine motion should be simulated by the solution of a complete six-degree-of-freedom mathematical-model representation. The hydrodynamic coefficients used in the mathematical model should be derived from design data, model data, and shipboard test data. If the latter two types of data are not available during the design phase of the trainer, the hydrodynamic coefficients should be derived and/or assumed from design data and then updated as the latter two data become available.

The ranges of the variables provided in the mathematical model will

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be as great as those attainable on the ship being simulated. These variables are the linear accelerations and velocities and the angular accelerations, velocities, and displacements. The depth will be scaled to go down to collapse depth and both pitch and roll angles will be scaled to ± 60 deg.

The minimal content of the mathematical model will include:

1. Moment equation damping

2. Deceleration due to displacement of each of the control surfaces

3. Discrete changes in accelerations due to coefficient changes for transition from fully surfaced to submergences, and vice-versa

4. Forward speed only

5. Weight and moment computations, assuming weight moment arms are constant or measured from the overall-ship center of gravity to individual-weight center of gravity

The coefficients, having surfaced and submerged values, should be changed discretely at applicable depths. The moment arms for each tank and the product of the amount of water times the moment arms for each tank will be simulated in the hydrodynamic portion of the computer complex.

The device should demonstrate recoverability effects of flooding, jamming, and combined flooding and jamming casualties as derived from ship or class recoverability study data. The simulated effects should produce trajectories to within five percent of the recoverability study data.

Sea-state controls will be operator controllable over a range of 0 to 10.

Depth should be based on distance from the surface to the fixed center of gravity of the submerged submarine. The surfaced condition should represent the keel depth corresponding to the condition of trim control equal to zero and all main, variable, and special ballast tanks empty. However, all indicator depths will reflect keel depth below the surface.

Flooding should be operator controlled as to rates and location. Rates to be simulated should simulate a pipe shear of the sizes of hull openings found in the type of ship simulated; for example, in Appendix D, casualty class II B. The flooding location (compartment) will be selectable by the operator. The floodable volume of

each compartment will be considered a cylinder with free surface effects approximated. The rate of flooding will reflect depth, and effects will be demonstrated relative to the center of gravity of the flooded compartment. Time to secure flooding will be continuously variable, controlled at the option of the operator/instructor to reflect immediate isolation or continuous flooding.

d. Equipment

The controls and indications provided on the trainer platform can be simulated and need not be actual equipment, but should appear realistic. Those activated must show proper dynamic responses. The indicators not activated dynamically should show normal indication.

The recommended scoring/feedback system will consist of a closed-loop television system, analog recorders, and events counters. If feasible, the recording equipment may be combined. The television system will employ recording and playback features.

All the malfunctions and casualties recommended earlier in Item 4 of this appendix should be evaluated to determine those for which one method of inserting failures can be used.

The selection of computer, logic, and input/output equipment should include consideration of cost and flexibility, that is, the method and time to change from class to class of ship.

The simulation of collision impact effects should be considered for further study. Simulation may involve the forces and moments produced by the colliding body parameters at the time of impact. The forces and moment effects would be simple and may be limited to effects on axial velocity, pitch moment, and roll moment. The parameters of the colliding bodies considered should be mass, angle of attack, and speed. The collision should be assumed to take place with a surface ship or a submerged submarine. Mass and speed would vary to include representation of ships both smaller and larger than the submarine simulated and of ships traveling both slower and faster than the simulated submarine.

APPENDIX G

TRAINING METHODS ANALYSIS

The functional training units (FTU's) of the training methods analysis (Section IV, Subsection Four, of this report) are presented herein. For each FTU, a matrix scheme (Tables G-I through G-VII) was applied to determine the best training approach, at the various training levels, for each training requirement. The numbers in each block of the matrix refer to the numbers assigned to the training requirements for respective FTU's in Table I. The letter associated with each requirement represents a judgment of the effectiveness of the training approach in satisfying the requirement. By the letter rating scheme, "a" indicates the preferred method, and "b," "c," "d" indicate second best, third best, and supplemental method, respectively.

The seven matrices (tables) present a summary of the training methods analysis and provide a cross referencing scheme by means of which the inquisitive reader can relate the results of the training requirements analysis, the general subsection of training methods, and the training approaches identified for each of the functional training units in Section IV, Subsection Four, Items 4 through 10.

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TABLE G-1 - SHIP CASUALTY CONTROL

Training levels	Training method						
	Classroom	Film	Demonstration	Procedural	Generalized dynamic	High-fidelity dynamic	Shipboard
Basic enlisted	1d, 2a, 3a, 6a, 14b	1d, 3d, 6b, 14d		2b, 3b, 14a	1b, 2a, 3a, 6a	NA	
Basic officer	2a 3a, 5a, 7a, 8a, 10a, 11a, 14b	3d, 5d, 8a, 10a, 12b, 14d		2b, 3b, 8c, 14a	2a, 3a, 5b, 7a, 8a, 10a, 11a	NA	
Upgrading enlisted	5a, 8c, 11a	5d, 8a, 10a, 11a, 14d			5b, 8b, 10b, 11b, 7a	5a, 8a, 10a, 11a	
Intermediate/transitional enlisted					10, 3b, 6c	1a, 2a, 3a, 4a, 6a	
Intermediate/transitional officer	5a, 10a, 11a	8a, 10a, 11a			2b, 3b, 7c	2a, 4a, 5a, 7a, 8a, 10a, 11a	
Advanced enlisted				14a	14	4a, 13a, 14	
Advanced officer				14a	14	5a, 7a, 8a, 9a, 10a, 11a, 12a, 13a, 14	

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TABLE G-II - FIRE CASULTY CONTROL

Training levels	Training method						
	Classroom	Film	Demon-stration	Procedural	Generalized dynamic	High-fidelity dynamic	Shipboard
Basic enlisted	2a 3c	2d, 3d, 5	5a		5a (discuss fire fighting)	NA	NA
Basic officer	2a, 3c	2d, 3d, 5	5a		5a	NA	NA
Upgrading enlisted							
Intermediate/transitional enlisted	1a, 2a, 3a, 4a	2d, 1a, 3d	1, 5a		3b partial		1a, 2a, 3a, 4a
Intermediate/transitional officer	1a, 2a, 3a, 4a	2d, 1c, 3d	5a		3b partial		1a, 2a, 3a, 4a
Advanced team enlisted							3a, 4a
Advanced team officer							3a, 4a

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TABLE G-III - FLOODING CASULTY CONTROL

Training levels	Training method						
	Classroom	Film	Demon-stration	Procedural	Generalized dynamic	High-fidelity dynamic	Shipboard
Basic enlisted	1b, 2a, 3b, 4a, 5a	1a,* 3b	1a*	7a	3a* 4a (partial) 5a, 6b, 7b	NA	2b, 3b, 6b
Basic officer	1b, 2a, 3b, 4a, 5a, 6b	1a,* 2b	1a*	7a	3a* (partial) 4a (partial) 5a, 6b, 7b	NA	2b, 3b, 5a 6b
Upgrading enlisted			1a	7a	5a, 7b	5a*	
Intermediate/transitional enlisted	2a,* 4a,* 5a, 3a	1a,* 2b, 4d	1a	7a	3a* (partial) 4a (partial) 6b, 5c		2a, 3a, 4a, 5b, 6b
Intermediate/transitional officer	2a,* 3a,* 4a, 5a	1a,* 2b, 4d	1a	7a	3a* (partial) 4a (partial) 5c (6b)	5a*	2a, 3a, 4a, 5b, 6b
Advanced team enlisted				7a	3a* (partial) 4a (partial) 5c, 6b, 7b (partial)	5a,* 7b	3a, 4a, 6a, 7c
Advanced team officer				7a	4a (partial) 3a* (partial) 5c, 6b, 7b (partial)	5a,* 7b	3a, 4a, 6a, 7c

*This is considered to be a critically mandatory training requirement.

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TABLE G-IV - ATMOSPHERIC CONTAMINATION RECOGNITION

Training levels	Training method						
	Classroom	Film	Demon-stration	Procedural	Generalized dynamic	High-fidelity dynamic	Shipboard
Basic enlisted	3a, 4a, 1b	4b	1a		3a	NA	NA
Basic officer	3a, 4a, 1a	4b	1a		3a	NA	NA
Upgrading enlisted DO and BCPO		4b		3a, 4a	4a (DO)	4a (BCPO)	3a
Intermediate/transitional enlisted	4a, 2a, 3a	3b, 2c, 3d, 4b	1a				2a, 3a, 4a
Intermediate/transitional officer	4a, 2a, 3a	3b, 2c, 3d, 4b	1a				2a, 3a, 4a
Advanced team enlisted							
Advanced team officer							

TABLE G-V - PROPULSION CASUALTIES

Training levels	Training method						
	Classroom	Film	Demon-stration	Procedural	Generalized dynamic	High-fidelity dynamic	Shipboard
Basic enlisted							
Basic officer							
Upgrading enlisted	1a	1d					
Intermediate/transitional enlisted					1b, 2b	1a, 2a	
Intermediate/transitional officer	1a	1d					
Advanced team enlisted					1b, 2b	1a, 2a	
Advanced team officer						1a, 2a	

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TABLE G-VII – SHIP SYSTEMS MONITORING AND CONTROL

Training levels	Training method						
	Classroom	Film	Demon-stration	Procedural	Generalized dynamic	High-fidelity dynamic	Shipboard
Basic enlisted (including refresher)	7a, 8b, 9b, 10b	7d, 8d, 9d		10a	8a		7a, 9a, 10a
Basic officer	1b, 3a, 4a, 10b			6c, 10a, 5a	1c, 3a, 4a, 6a	NA	1c, 3b, 4b, 10a
Upgrading enlisted (DO and BCPO)	1b,$^+$ 2b,$^+$ 3a,$^+$ 4a,$^+$ 5b,$^+$ 6a$^+$			4a,$^+$ 5a$^+$	1c,$^+$ 3b,$^+$ 4b,$^+$ 5a,$^+$ 6c$^+$	1a,$^+$ 3a,$^+$ 4a,$^+$ 5a,$^+$ 6a$^+$	1c,$^+$ 2a,$^+$ 3b,$^+$ 4b,$^+$ 5a,$^+$ 6a$^+$
Intermediate/transitional enlisted	8a, 9b, 10b	7a					7a
Intermediate/transitional officer	8a, 9b, 10b	3a, 4a, 7a				3a, 4a	3c, 4c, 7a
Advanced team enlisted							8a, 9a, 10a
Advanced team officer						1a, 3a, 4a, 6a	

$^+$Indicates training in upgrading forward auxiliarymen and IC electricians to BCP operator.

GLOSSARY

ADCP	Aft damage control party
AMC	Automatic maneuvering control
AMR	Auxiliary machinery room
AMRLL	Auxiliary machinery room lower level
AMRUL	Auxiliary machinery room upper level
AMS	Auxiliary machinery space
ASW	Auxiliary saltwater system
AUW	Advanced underwater weapons
BCP	Ballast control panel
BCPO	Ballast control panel operator
BuPers	Bureau of Personnel
BuShips	Bureau of Ships
CIP	Combined instrument panel
CO	Commanding Officer
COMSUBLANT	Commander, Submarine Force, U.S. Atlantic Fleet
COMSUBPAC	Commander, Submarine Force, U.S. Pacific Fleet
COW	Chief of the watch
CPO	Chief petty officer
DCA	Damage control assistant
DO	Diving officer
DOOW	Diving officer of the watch
EBS	Emergency breathing system
EOOW	Engineer officer of the watch
EPCPO	Electric plant control panel operator
EPM	Electric propulsion motor

GLOSSARY

EPOOW	Engineering petty officer of the watch
ERLL	Engine room lower level
ERUL	Engine room upper level
FBM	Fleet ballistic missile
FDCP	Forward damage control party
FTU	Functional training units
FWP	Fairwater planes
H	Helmsman
IC	Interior communication
INSTTACTDIV	Instructor, Tactical Division
JO	Junior officers
KR	Knowledge of results
MBT	Main ballast tank
MO	Medical officer
MSW	Main seawater system
OBA	Oxygen breathing apparatus
OOD	Officer of the deck
PO	Petty officer
RC	Radar controller
RPCPO	Reactor plant control panel operator
SIB	Ship's information book
SORM	Ship's organization and regulation manual
SP	Stern planesman
SPCPO	Steam plant control panel operator
SPM	Secondary propulsion motor
SSBN	Fleet ballistic missile (Polaris) nuclear submarine

GLOSSARY

SSMG	Ships service motor generator
SSN	Attack type nuclear submarine
SSTG	Ships service turbine generator
SUBSAFCEN	Submarine safety center
USNTDC	U.S. Naval Training Device Center
VBT	Variable ballast tank
XO	Executive officer

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13. ABSTRACT The study confirmed previous research and opinions that plane failures and flooding are the most critical of the casualties to be trained. Critical factors for recovery and skill behaviours to be trained were identified. These factors (1) emphasize immediate detection and automatized (immediate) emergency response; add as critical requirements for team training, judgments by the Officer of the Deck (OOD) and the upgrading of enlisted men to stand Diving Officer (DO) and Ballast Control Panel (BCP) Watches; (3) emphasize the need for programs of standardized alternate recovery actions and guidelines related to depth and speed bands; and (4) emphasize the need for adjustment of recovery action to operational requirements, such as the tactical situation and concealment by noiseless submerged running for as long as possible.

The recommendations include characteristics of high-fidelity dynamic ship control trainers for SSN's and SSBN's, respectively; a flooding demonstration trainer; a communications trainer; and a BCP emergency procedures trainer. The recommendations also include the use of basic generalized dynamic ship control trainers (for example, Device 21B56A), a training course for upgrading nonline officers and enlisted men to stand the DO watch, the establishment of standardized casualty recovery procedures and guidelines (including standardized flooding classification and reaction), the development of recoverability data for less than "worst case" casualites, and an additional study effort on damage control training approaches.

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